THE EAST AFRICAN AGRICULTURAL JOURNAL

Issued under the Authority of the East African Governors' Conference and published every other month
JANUARY, MARCH, MAY, JULY, SEPTEMBER, NOVEMBER

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EDITORIAL NOTES

Tropical Soils in Relation to Tropical Crops.

The Imperial Bureau of Soil Science has just issued a 60-page booklet under the above title.* A foreword explains that the subject-matter is strictly defined by this title; no attempt has been made to give cultural details of the crops as an agricultural textbook would, only to give brief generalized accounts of the soils that carry particular crops in stated parts of the tropics. There are eleven chapters: Sugar Cane; Rice; Cotton; Citrus; Bananas; Coco-nuts; Rubber; Tobacco; Coffee; Cacao; Tea. In each chapter the treatment is in short sections under geographical headings, e.g. India, W. Indies, Java, Brazil, etc. As the material has been gathered solely from published papers, it is admittedly very uneven; naturally it is best for those regions in which there is already a history of intensive soil studies on modern lines. This is well reflected in the chapter on cotton, where the soils that carry the crop in U.S.A., Egypt and the Sudan, and U.S.S.R., are very intelligibly described, those of India less so, while East Africa goes unmentioned. There is therefore disappointment for the East African reader if he seeks in this booklet direct local guidance on the choice of soil for crop, for though all the crops dealt with, except rubber and cacao, are of economic importance in one part or another of East Africa, agronomic experience with them is as yet imperfectly analysed and recorded. Only in relation to one crop (coffee) has intensive soil work been

* Technical Communication No. 34, Imperial Bureau of Soil Science, Harpenden, Herts, England; 2/6.

embarked upon, and even with that the work is still in its early days, and few definitive results have been published. There is, however, a great deal in this publication that will make it a useful temporary work of reference (if only to the *gaps* in our ordered knowledge of soil and crop affinities), pending the appearance of a less abbreviated treatment of the subject. We cannot but feel that the subject would perhaps have been better handled in more leisurely fashion in the form of a series of one-crop monographs.

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A New East African Scientific Journal.

For more than twenty-five years Kenya has possessed a local scientific journal; Uganda began one of high standard three years ago; now at length a similar publication has been started in Tanganyika.* The need for such a journal is certainly no less than in the other territories. Indeed, it may be more, for much of the natural science of Tanganyika, ranging from geography to ethnology, is very badly documented, and moreover a large proportion of what has been published is available only to those who can read German. The Territory contains whole districts and great natural features about which no description of any sort is available in the English language. Knowledge of local flora and fauna, not excepting the human members, remains equally imperfect and unco-ordinated. Fruitful interest cannot fail to be stimulated by a journal that has so much to tell us of our more or less immediate surroundings, and at the same time opens its pages without discrimination to whoever has something interesting to say and will take a little trouble to say it.

The two numbers so far issued have a wide range of appeal. The general natural history includes papers on the geography of the Territory, both general and local, on the retreat of the Kilimanjaro glaciers, and on the nesting habits of some of the birds. Rather more than half the total content is concerned with archæology and with some aspect of African tribal life. Several papers reflect the increasing interest that is being taken in native medical materials and treatment. Three contributions are directly concerned with agriculture. The description of the rotational system used on Ukara Island in Lake Victoria provides an astonishing example of what admirable methods of cultivation a native community can evolve for itself under pressure of necessity.

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Report of the Kenya Department of Agriculture.

We commend to the notice of all readers in Kenya Colony the account of the work of their Department of Agriculture, which has been recently published.* Although a summary, Vol. I of the report runs to 130 pages, and contains much information of interest on many phases of the agricultural industry. Starting with a general survey of agricultural progress in Kenya during 1935, it is mainly occupied by summaries of the work of the Plant Industry and Animal Industry Divisions, prepared by the respective Deputy Directors in charge of them.

Volume II contains the reports of certain specialized officers, dealing with

* *Tanganyika Notes and Records*, published half-yearly. Annual subscription 10/- (5/- a single copy), payable to the Hon. Treasurer, *Tanganyika Notes and Records*, c/o Treasury, Dar es Salaam.

* Kenya Colony and Protectorate, Department of Agriculture Annual Report, 1935, Vols. I and II; Government Printer, Nairobi, 2/50 each.

plant pathology, grassland improvement, plant breeding, soil and other chemical work, entomology, and veterinary research. In addition, there are included the reports of the Provincial Agricultural Officers in charge of work in the Central, Nyanza and Coast Provinces. The report of the Senior Coffee Officer is omitted, since it has already been published in this Journal;† similarly, the report of the Agricultural Officer, Njoro, dealing with experimental work upon crops and soil management in the Rift Valley and Molo areas, appears as an article in this number of the Journal.

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REPORT OF THE EAST AFRICAN AGRICULTURAL RESEARCH STATION, AMANI.

The last report by Mr. Wm. Nowell, as Director of the East African Agricultural Research Station, has recently been issued by the Colonial Office.* He records satisfactory progress in all departments, hampered only by the shortage of staff, which has now become an urgent problem. The main part of the report deals with research on sisal and coffee. We notice that the raising and study of seedlings from species of *Agave* is well advanced, and that Blue Sisal (*Agave amaniensis*) is attracting the interest of growers, whose demands for planting material exceed the available supply. The coffee section deals mainly with the physiological researches, the discovery of a parasite of *Antestia* by the Entomologist, and the outstanding problem of the liquoring quality in coffee. The results of grafting *arabica* coffee on to stocks of *robusta* and *liberica* have failed to come up to expectation. Notes are added upon local experience in the cultivation and chemical studies of *Cinchona*, *Derris*, *Mundulea* (a native African fish-poison), and *Aleurites*.

The sectional reports of research officers follow. In addition to the subjects mentioned above, they deal with studies of virus diseases of plants, soil surveys, insecticides, systematic botany, and ornithology. A scheme for the development of the Kwamkoro Estate, adjacent to Amani, under *robusta* coffee, *Cinchona*, *Aleurites* and *Derris*, has made good progress.

† *East African Agricultural Journal*, II, No. 3. Nov., 1936, p. 178.

* Eighth Annual Report, East African Agricultural Research Station, Amani, 1935-36; H.M. Stationery Office, 1/-.

Experimental Work with Crops and Pastures in the Rift Valley and Molo Areas of Kenya, 1934—1936

By R. S. BALL, *M.A., Dip. Agric. (Cantab.), A.I.C.T.A., Agricultural Officer, Department of Agriculture, Kenya Colony.*

The experimental work carried out in the Rift Valley Province of Kenya and in the high-altitude areas has of late years tended to change in character. Formerly, extensive crop trials were carried out in order to diversify existing systems of farming, so that the farmer's eggs should not all be in one basket. In addition, extensive trials were carried out of green manures as a means of restoring fertility to arable land. As a result, a large number of crops were proved to be suitable for the various districts, in addition to the staple crops already being grown.

One of the chief means of restoring fertility to worn-out arable lands is by the extension of grassland, or the natural reversion to grass of arable lands, together with controlled management. Further, it is doubtful whether many of the alternative cash crops tried are likely to be grown on sufficient acreages to enable them to be used in strict rotation with the staple crops, owing either to lack of markets, or to practical difficulties of cultivation. It becomes increasingly necessary to devise systems of alternate husbandry for resting and recuperating arable land, and for the eradication of diseases to which these staple crops under a one-crop system may be subject.

The results from green-manuring trials carried out in the area have been too inconclusive to justify the use of this practice on a large scale as a means of restoring fertility. Work has latterly been directed rather to the possibilities of the ploughing-in of crop residues than to the use of particular crops grown for the purpose.

Extensive trials are being carried out of indigenous and exotic grasses, and also large-scale trials of the best of these under grazing conditions.

While it is now possible to recommend for most areas suitable crops, grasses, forage and fodder crops, and, based on these, possible rotations of grass and arable land, there remains much work still to be carried out. Accurate figures of yields of forage and fodder crops, of indigenous and exotic grasses under different conditions, and the feeding value of these grasses and plants at different times of the year should be determined in order that the best methods of rationing animals can be ascertained. The management and manuring of grassland also require close investigation, since preliminary results to date indicate that organic manuring on certain types of grassland may very greatly increase its productivity.

The more extensive use of crop residues for restoring fertility to worn-out arable land and the best means by which they can be incorporated in the soil are also being investigated.

Failures of crops, in particular bean varieties which have been imported for trial, have in some instances been due to disease or some other factor which can be partly controlled by selection. Where it is considered that the crop has economic possibilities, attempts are being made to select resistant strains.

Attention is also being paid to cultural methods for various crops, such as pyrethrum, where the technique of cultivation by the farmer is still in the experimental stage.

Conditions in the Area.

The area ranges from altitudes of 5,500 feet up to over 9,000 feet, so that conditions are extremely varied, necessitating the diversification of experiments and trials. Three main centres are in existence: Njoro, at an altitude of 7,100 feet; Rongai, at 6,100 feet, and Molo, at 9,000 feet. In addition, experiments are performed on farms intermediate to these stations where peculiar conditions of soil, climate, or other factors render it desirable.

At Njoro, the work is carried out on the Plant Breeding Station, where facilities exist for large-scale trials on pastures, etc., which can be observed and grazed under a controlled system. At the other centres this work is done in a similar way, or on a larger scale in co-operation with farmers, and wherever possible the results of experiments which have been successfully tried on a small scale are re-duplicated under actual farming conditions.

A brief description of the centres at which experimental work was carried out in 1935 is appended:—

1. *Njoro.*—Altitude, 7,100 feet. Rainfall for 1935, 34.18 inches. There are two chief rainy seasons, April-May and July-August. December, January and February are the driest months. The soil at Njoro is a loam, fairly well supplied with humus, which dries out fairly rapidly. Maximum and minimum temperatures average 75° F. and 44° F. respectively.

2. *Rongai.*—Altitude, 6,100 feet. Evaporation during the day is very high in this valley, and long dry spells are experienced. Day temperatures are higher than at Njoro, and the dry season experienced is much more severe. The two chief rainy seasons are April-May and July-August. The soil is red in colour, has a fairly high clay content, and dries out very rapidly. It is deficient in humus as a result of extensive cultivation.

3. *Ngata.*—Altitude, 6,500 feet. The conditions here are similar to those at Njoro, except that the soil is a volcanic ash. It retains moisture well, better than the soils at Njoro, but is subject to long dry periods during the growing season, and the soils are now deficient in humus, although they recuperate very rapidly under a grass cover. Day and night temperatures are a few degrees higher than at Njoro, but the total rainfall is approximately the same.

4. *Molo.*—Altitude, 9,000 feet. Frost is experienced at certain seasons of the year; rainfall is heavier than at Njoro, and more uniformly distributed, actually totalling nearly 50 inches in 1935, which was a very wet season. The evaporation is relatively low as compared with Njoro. The soil is a dark loam, fairly rich in humus. Both day and night temperatures are on the average several degrees lower.

Maize.

Improvement of Maize Yields.

A.—Use of Activated Compost at Rongai.—Three rates of applications of activated compost were tried:—

3 tons per acre,
6 tons per acre,
8½ tons per acre.

Compost made from maize trash was used, and the experiment took the form of a randomized plot. In spite of a dry year, heavy yields were obtained from all plots, due to very early (February) planting. Results were as follows:—

	Yield in bags per acre.	*Per cent.*
Control ...	13.3 ...	100
3 tons ...	16.6 ...	124.7
6 tons ...	17.8 ...	133.7
8½ tons ...	18.9 ...	142.1

Statistical analysis: 8½ tons greater than 6 and 3 tons; 3 tons greater than control.

This experiment will be continued for at least two years, to test the residual effect in the soil. Results show that the greatest percentage rate of increase is obtained in the first year by an application of three tons per acre, and that further applications tend to show a diminishing rate of increase. In view, however, of the fact that the season was a dry one this might naturally be expected, due to the stimulation of excessive leaf growth by the heavier applications. This state of affairs might be reversed in a wet season.

In 1936 the experiment was replanted without any further addition of compost, and results were as follows:—

	Bags per acre.	*Percentage of mean.*
Control ...	13.49 ...	100
3 tons ...	13.84 ...	102.6
6 tons ...	15.03 ...	111.4
8½ tons ...	16.71 ...	123.8

Eight tons is significantly greater than 3 tons and control, but the increase due to an application of 3 tons has completely disappeared in one year.

B.—Ploughing in of Maize Trash.—The manufacture of activated compost on the large farm is often precluded by the cost of obtaining water and transporting the maize trash. An experiment was therefore started in 1936 to compare the effect of ploughing in of maize trash with that of the normal practice of burning. It is considered that maize trash ploughed in by itself might induce an initial nitrogen starvation of the young maize planted as a succeeding crop, due to the fact that the trash had not decomposed at planting time. Therefore the experiment also includes plots where a small addition of compost has been made, with the object of giving a stimulus to the young maize until the trash has completely decomposed. The addition of superphosphate together with the trash itself, when ploughed in, is also being tried with the same object.

It is realized that the effects of ploughing in of trash will be cumulative over a period of years, and, for this reason, it is intended that the experiment shall be a long-term one.

Results for 1936 were as follows:—

	Yield in bags per acre.	*Percentage of control.*
1. Control ...	17.28 ...	100
2. Trash ploughed in	17.35 ...	100.4
3. Trash and compost ploughed in	16.93 ...	97.9
4. Trash and superphosphate, 200 lb. per acre ...	17.91 ...	103.0

Statistical analysis: 4 is greater than 3, 2, 1.

C.—Green Manure Experiment at Ngata.—This experiment was designed to test, on a volcanic ash soil deficient in humus, the effects of ploughing in of crop residues, such as wheat and barley straw, against compost and green manuring. Owing to the indifferent results obtained from green manuring and the necessity for the sacrifice of a cash crop for a whole year in order to grow the green manures, it is hoped that this cheaper method of ploughing in straw may be effective. The beneficial effect of ploughing in barley straw at Rongai has been described in the past. The following experiment was laid out:—

1. Control. Planted with maize.
2. Compost and maize.
3. Sunflower planted early and ploughed in, followed by New Zealand grass pea.
4. Wheat straw ploughed in after harvesting.
5. Barley straw ploughed in after harvesting.

In the case of 4 and 5, early and late ploughing in of the straws are being tried, also addition of superphosphate at time of ploughing in. The whole experiment is to be planted in maize in 1936

and yields will be compared. The average yield of maize in the control plots in 1933 (a drought year) was 3.46 bags per acre.

The dry season experienced again emphasized the difficulty of growing green manure crops in this area, as the bulk of both sunflower and New Zealand grass pea was small, whereas the bulk of wheat straw was fairly satisfactory. It is hoped that as a result of this experiment, some measure of the value of ploughing in of wheat and barley stubbles will be obtained, and also the best time of the year to plough them in will be ascertained.

D.—Green Manure Randomized Block at Rongai.—Owing to the severe drought in 1934, which rendered the growth of all green manure crops slow, this experiment was modified in 1935, so as to compare the effect of barley and wheat straws (after harvesting the grain) and Madagascar butter beans as green manures. These crops were therefore planted on some of the plots which were planted to maize in 1936. The plots planted in maize in 1935, after the 1934 green manuring, yielded the following results:

	Yield in bags per acre.
1. Maize	10.94
2. Madagascar Butter Bean, Cash Crop	10.44
3. Madagascar Butter Beans, Ploughed in early	13.86
4. Madagascar Butter Beans, Ploughed in late	11.46
5. Madagascar Butter Beans, Mulched late	9.78

Statistical analysis showed no significant results.

Results in 1936 were as follows. It should be noted, however, that the cereal crops, wheat, and more particularly barley, made very poor growth, due to drought in 1935. The amount of straw ploughed in, in the case of barley, was therefore very small:—

	Yield in bags per acre.		*Percentage of control.*
Maize after wheat straw ploughed in	11.21	...	121.8
Maize after barley straw ploughed in	9.34	...	101.5
Control: Maize after maize straw ploughed in ...	9.20	...	100.0

E.—Pumpkin in Maize Green Manure Trials.—A trial was made of interplanting maize with native pumpkins, with the idea of rendering all rainfall available by preventing run-off. The pumpkins made a complete cover to the land, and certainly caused the water to percolate slowly into the ground. Unfortunately, a very dry spell when the maize was flowering caused the pumpkin plot to drought very badly owing to competition. Yields were as follows:—

	Bags per acre.
Pumpkins in maize ...	... 4.47
Maize alone	... 5.82

In 1936 this experiment was planted in maize, and the growth to date on the plot on which the pumpkins were ploughed in has been slightly superior to the control. Whether the increase in yield will be sufficient to counteract the lower yields obtained in 1935 and yield an ultimate total increase cannot yet be determined.

Seed Maize Competitions.

These have been carried out at two centres yearly, in 1934 and 1935 at Rongai and Njoro, and in 1936 at Crater Stream and Njoro. Entries totalled 34 in 1935, and results were published in the Press.

Included in these competitions, short term maizes were tried in 1935, with the idea that these might prove useful in the drier areas, such as Rongai. One, Muratha, proved to be about four weeks earlier, and at Rongai it escaped the severest dry period.

A trial of a synthetic white maize imported from Potchefstroom in 1936 has, however, been successful, and it appears that this maize, which is considerably earlier than the other white maizes, will yield well. It is not expected, however, that it will yield as well in a wet season as the ordinary long-termed white maizes, but its average yield over a period of years in a dry area would probably be higher, and it will therefore be given a more extended trial.

Canning Corns.

Golden Bantam appears to be promising as a sweet corn for canning. It has made good growth during 1936.

Crop Trials.

Linseeds.

Variety trials carried out in 1934 indicated that the varieties Morocco and Redwing were most suitable under Njoro conditions, while Redwing was the most suitable for Rongai on account of its early maturity. The trials were continued in 1935. A disease, identified by the Senior Plant Pathologist as *Macrophomina phaseoli*, appeared in the Morocco variety—the variety which has proved most suitable for oil crushing. Redwing and a Pusa linseed (H.21) proved themselves resistant to this infection. At Rongai, a yield of four bags per acre was obtained from Morocco linseed, and no disease was observed. A trial of the Pusa linseeds, which had yielded well at Njoro in 1934, was made at Molo, but they did not prove satisfactory at this high altitude as compared with other varieties, such as Morocco.

In 1936 the two varieties, Morocco and Redwing, were planted at Njoro in an experiment in which some of the seed was treated with Agrosan G., with the idea of controlling seed-borne diseases. There was a significant difference in the stand figures for both varieties due to seed treatment, and subsequently, in the case of Morocco, there was a statistically significant increase in yield due to treatment with this mercurial dust. This increase was not, however, obtained in the case of Redwing, since the stand on the dusted plots was so thick that a good deal of it died out during a dry period in June. It would appear that dusting of the seed with a mercurial dust is a practice that can be definitely recommended as a means of securing a good stand of linseed.

Flaxes.

Four varieties bred for flax fibre were sent for trial at Molo. All grew well, and the length of straw obtained was satisfactory. Fair yields of seed also were obtained. There was no sign of wilt or other disease. Yield figures for seed were as follows: —

	Bags per acre.
Liral Crown	2.7
Liral Monarch	2.2
Stormont Cirrus	3.7
Stormont Gossamer	2.9

These have been put in a variety trial at both Molo and Njoro in 1936. The difference in length of straw between the Stormont and Liral varieties is marked, both the Stormont varieties being about four inches longer than the Liral varieties, but these latter appear to be finer in straw and probably in fibre.

Sugar Beet.

A trial was made of this crop at all three centres—Njoro, Molo and Rongai. It showed considerable promise at Njoro and Rongai as a fodder crop, growing well but slowly, in spite of somewhat dry conditions. Wet and cold weather at Molo discouraged it, and growth made was poor. It is probable that it may prove

useful as a forage crop for these lower altitudes, but it is doubtful whether it offers great possibilities for seed production, on account of the highly organized seed-growing trade with which it would have to compete, both in Great Britain and on the Continent.

The crop has continued to grow at Njoro during 1936, and had not commenced to come into flower. It is suggested that a stimulus might be given by transplanting the roots, and it is proposed to undertake this.

White Sunflower.

The crop was tried at both Rongai and Njoro in 1935, and showed considerable promise. It proved drought-resistant and at Rongai yielded about eight bags of seed to the acre. Its period of maturity at Njoro proved to be 5½ months. The overseas price at present is about £8 per ton.

Marrowfat Peas.

In 1934, large plots of the three varieties, Harrison's Glory, Dutch Marrowfat, and Japanese Marrowfat, which were the best of many tried in past years, were laid down, with the object of comparing yields and also of evolving some simple method of harvesting technique. Two dates of sowing (early July and early August) were used, but the yields were rather low on account of the dry season. As far as harvesting technique is concerned, it appears that if the plants are harvested *in toto* when the *bottom* pods are commencing to yellow, and all the material put straight into a maize crib or other suitable store, leaving a space at one end to permit of turning, slow drying will occur with the minimum amount of bleaching. The whole mass should be turned every two to four days, depending on conditions of moisture in the atmosphere outside, and drying takes about three to four weeks before the samples are fit to thresh.

In 1935 a spacing experiment was laid down at Njoro to determine the best width for spacing Dutch Marrowfat peas. Two distances of spacing, 16 in. and 8 in., were adopted, the seed rate being the same in both cases. The experiment took the form of an alternate drill strip. Statistical analysis yielded no significant result:—

8 in. spacing = 4.55 bags per acre.
16 in. spacing = 3.59 bags per acre.

A further test was made in 1935 of the harvesting method used in 1934. The whole haulm was lifted when the bottom pods had begun to yellow, and dried in a maize crib, being turned when necessary to prevent heating. A most satisfactory sample of excellent colour resulted. The actual figures of analyses of the peas when threshed are as follows:—

Green peas	86 per cent.
Bleached peas	8 per cent.
Split and broken peas ...	2 per cent.
Blown peas	3 per cent.
Insect-damaged peas ...	1 per cent.

The method proved as successful at Molo as at Njoro, and an excellent sample of Harrison's Glory peas was obtained.

Trials of two varieties of canning peas were made at Njoro and Molo, and one from the Milton's Preserving Co. The same technique was used for drying as in the case of the Marrowfat peas, and excellent samples resulted. The yields of these small blue peas were, however, considerably lower than those of the Marrowfats, and for this reason are probably not worth further trial. A small sample has, however, been issued in 1936 for planting for trial at the local canning factory, as there is said to be a demand for a smaller type of canned pea at a higher price.

Canning Beans.

A further trial was made of the most successful of these varieties tried in 1934, and again Keeney's Stringless Green Refugee proved very satisfactory on account of its yield and resistance to bacterial blight. Hodson Wax N.39 also yielded very satisfactory results. Since there is now a fair acreage of Keeney's Stringless Green Refugee being grown in the district, it would not appear to be necessary to carry out further trials of these canning varieties.

It is proposed to carry out further trials with varieties superior to Keeney's in disease resistance now being grown in the United States. It is hoped to obtain some of these newer varieties for trial in 1937.

Bean Crosses and Selections.

The work of selection of crosses made at Njoro has continued, resistance to bacterial blight being one of the chief determining factors in selection. Three selections were outstanding in this respect in 1935, and will be multiplied further.

Continued selection at Njoro of Canadian Wonder for resistance to bacterial blight has proved successful, and resistant strains were multiplied in 1936, when the incidence of the infection was exceptionally high; in fact, sufficient to destroy to a large extent non-resistant strains. These selected strains have shown themselves highly resistant. This work has been extended to the Rose Coco variety and also the Madagascar butter beans at Njoro and Rongai. Selection is being carried out on strains of the Madagascar beans which have proved themselves resistant to "yellow eye". It would appear unlikely, however, that any resistance to bacterial blight with this variety of bean can be obtained at Njoro (7,100 feet), but it is hoped that successful results will be obtained for the lower altitudes where the crop is normally grown. It is doubtful whether it will be possible to extend the limit of its cultivation. Results to date with Rose Coco are, however, promising.

Potatoes.

(*a*) *"Virus Free" Trial.*—Njoro-grown Kerr's Pink has degenerated badly, due to virus diseases. The non-"virus-free" seed grown at a higher altitude has yielded the most satisfactory results. Innishowen "virus-free" from Mau Summit is superior to similar seed once grown at Njoro, which suggests that deterioration due to virus has occurred after being grown once only at Njoro.

Latterly, these strains have been multiplied in order to test the length of time before degeneration sets in. Results to date indicate that the superiority of those strains derived from the high altitudes persists for at least two years.

(*b*) *Cultivation Trials.*—A cultivation experiment was carried out on the Kerr's Pink variety in 1935. The object was to compare the cultivations usually given to the crop in this country with those given in Europe, where they are much more thorough, and consist of ridging and breaking down the ridges three times. Results when analysed statistically were significantly in favour of thorough cultivations, and indicate therefore that adequate attention has not been paid to cultivation in Kenya.

A subsoiling experiment, using the various strains of Kerr's Pink as seed, has been laid down at Njoro in 1936, the subsoiler being worked along the bottom of furrows, in order to break up any pan that might be present. A fair amount of damage was done by early blight, which caused the crop to ripen prematurely, so that results were inconclusive. There was no statistically significant increase on the subsoiled plots.

Barleys.

A considerable number of barley varieties have been tried out at the various centres in the district, the results from one carried out in 1934 at Njoro being given below:—

	Yield per acre.	*Period of growth.*
Chevalier	7.72 bags	120 days
Colsess	4.40 bags	120 days
Regal	3.53 bags	125 days
Spratt's Archer	2.53 bags	160 days

Statistical analysis: Chevalier yielded significantly greater than Regal, Colsess, and Spratt's Archer; Colsess yielded significantly greater than Spratt's Archer.

Although the shorter termed varieties were favoured in a dry season, yet the results are sufficiently definite to indicate that Chevalier is the heaviest yielding variety under Njoro conditions.

In 1935, a trial of five varieties was made at Njoro:—

Webb's New Cross,
Chevalier,
Spratt's Archer,
Regal,
Colsess.

Of these, Chevalier, as in 1934, yielded the best, and it would appear that, for uncertain rainfall conditions, it is the most suitable variety on account of its short period of maturity. The varieties yielded as follows:—

	Bags per acre.
Chevalier	9.00
Webb's New Cross	3.03
Spratt's Archer	2.98
Colsess	1.29
Regal	1.12

A series of Palestine and Greek barleys were tried for the second time at Rongai. These six-rowed barleys appear to be somewhat more exacting in both soil and rainfall requirements than the two-rowed varieties. Palestine 41 was, however, outstandingly the best, yielding 8 bags per acre, while Palestine 15 yielded 7 bags.

In 1936, results of further trials of these Palestine and Greek barleys at Rongai have shown that both Spratt's Archer and Chevalier are superior to them in yield and length of straw. Chevalier has proved itself to be the most suitable rapidly maturing variety in this area.

FORAGE CROPS.

A.—Rongai.

The principal forage crops tried here during 1935 consisted of—

Napier grass,
Uba Cane,
Oat and Vetch mixtures,
Pumpkins,
English Rye,
Hubam Clover,
Lucerne,
Teff grass,
Ka-lu-a Soya Bean,
Giant Rape.

Napier Grass and Uba Cane.—These crops have proved very drought-resistant. There is, however, a very wide difference in the rate of growth, Napier grass having yielded about three times the bulk of herbage during the year. Uba Cane may have its place as a forage crop, on account of its high sugar content and great palatability. It remained green through extremely dry periods.

Oat and Vetch Mixtures.—Mixtures of Biffen's oat and purple vetch were grown. The oats were badly droughted and never came into ear; the purple vetch, however, stood the drought well, and when late rains came it grew afresh and yielded a fair hay crop, although somewhat woody at the bottom. It is certainly worth further trial in mixture. If grown alone, it would probably be very difficult to cut on account of its matted nature.

Pumpkins.—Three varieties were grown, of which Distin's, imported from South Africa, proved the quickest and heaviest yielder. On account of its very

high moisture content, this crop might prove useful in the dry season, when water for stock is often scarce.

English Midsummer Rye.—This rye proved too slow for Rongai conditions. Although it stooled well, it was badly droughted and never came into ear.

Ka-lu-a Soya Bean.—This made excellent growth and stood the drought well. From the plot a yield equivalent to two tons per acre of hay was obtained. It is therefore worth further trial as a hay crop in this area. Unfortunately, it proved to be a very shy setter of seed, and little was harvested.

Giant Rape.—This proved difficult to establish, on account of sawfly damage in the early stages, but otherwise it made good growth and appeared fairly drought resistant. It is doubtful, however, whether any farmers would be justified in planting more than a small acreage of *Brassica* crops under Rongai conditions, on account of the difficulty of their establishment.

Hubam Clover.—This plant again proved its value as a drought-resistant fodder crop, for it yielded three cuts during the year, and in one case there was no effective rainfall between two cuts.

Lucernes.—It is somewhat doubtful whether these are likely to be of much value under Rongai conditions unless irrigated. The growth made during the year was poor, and little reliance could have been placed on them as fodder crops. Of the varieties tried, Hairy Peruvian yielded the greatest bulk during the year, but only two cuts were obtained. In view of the fact that other forage crops will yield a considerably greater bulk of herbage under dry conditions, the lucernes are probably not worth further extensive trial in this area.

Teff Grass.—This grass was ready to cut for hay two and a half months after sowing, when it had attained a height of 20 inches. No second cut was obtained, the plants dying back completely. The bulk of herbage obtained was not great, equivalent to a hay crop of about 15 cwt. per acre. It is doubtful, therefore, whether the grass is likely to prove of much value as a fodder crop under Rongai conditions. Its chief value would appear to be in its ability to yield a small crop so soon after planting. It might therefore prove of some use after a period of severe drought or locust infestation.

During 1936 continued trials of these crops have been carried out, and Napier grass, Uba cane, and the oat and vetch mixture proved their value particularly. The oat and vetch mixture sown at the rate of 30 lb. per acre of Biffen's hybrid oat and 25 lb. per acre of purple vetch, yielded a hay crop of nearly four tons per acre of excellent quality. A mixture of oats and a field pea did not prove a success under Rongai conditions, as the peas could not compete successfully with the oats in mixture. It is suggested that future work in this district should be devoted to a comparative yield trial at different times of the year of the most successful of these forage crops, in order to determine their value as dry season crops.

B.—Njoro.

The following fodder crops were under trial during 1935:—

Vetches,
Silage mixtures and Hay (Oat and Vetch; Oat and P.B.I. P.50 pea; Oat and New Zealand grass pea),
Napier grass (from Songhor and imported),
Uba Cane,
Sainfoin (*Omobrychis sativa*),
Pampas grass (*Gynerium argenteum*),
Pumpkins,
Hubam Clover,
Kales, Cabbages and Giant Rape,
English Midsummer Rye,
White Mustard.

Oat and Vetch Mixtures.—Different seed rates of both oats and vetches were used in order to determine the optimum rate. Both purple and woolly pod vetch were used. Purple vetch proved to be the most suitable for the mixtures, owing to the fact that it is quicker than woolly pod, and it climbed more readily round the oats, thus rendering it easier to cut. Owing to its creeping nature, a considerable amount of the woolly pod was left on the ground after the mower had passed.

The optimum seed proved to be:—

Purple Vetch	...	30 lb. per acre.
Biffen's Oat	...	34 lb. per acre.

This yielded an extremely heavy bulk, in spite of somewhat dry conditions during growth, and a hay which proved very palatable to cattle.

Silage Mixtures.—Large-scale trials were made of oat and P.B.I. P.50 pea mixtures, also oat and New Zealand grass pea mixtures, as silage crops. The very heavy growth and tillering capacity of the Biffen's oat showed definitely that New Zealand grass peas are incapable of competing in mixture with it. The P.B.I. P.50 pea, which was drilled in the oats three weeks after the latter was seeded, again proved a satisfactory mixture, and a heavy yield was obtained. Several seed rates of this mixture were tried, the following proving most satisfactory:—

P.B.I. P.50 Peas	...	80 lb. per acre.
Biffen's Oat	...	55 lb. per acre.

A yield of approximately nine tons of silage per acre was obtained from this mixture, although conditions were rather dry during growth.

Trials were again carried out with the use of raw cane sugar molasses in the process of ensiling, and a one per cent solution, watered on as the pit was being built, proved to yield an extremely palatable silage.

Napier Grass.—The Songhor Napier grass has proved slightly the more drought resistant of the two varieties, but the total bulk obtained from the imported grass was found to be greater, since cuttings were made frequently.

Uba Cane.—This grew slowly at Njoro, but shows signs of being drought resistant. It is probably, however, more suited to the lower elevations.

Pampas Grass.—This grass, although very difficult to establish on account of the slow growth in the initial stages, has proved extremely palatable to cattle and very drought resistant. It may readily prove to be a useful dry season crop, and is worth extended trial.

Pumpkins.—As at Rongai, Distin's proved the quickest maturing and heaviest yielding of the three varieties tried, and is likely to prove of value for the dry season.

Sainfoin.—The seed of this crop was imported from England. Unfortunately, it grew very slowly, although it proved fairly simple to establish. It is probably worth trial for another year.

English Midsummer Rye.—This rye has grown very slowly at Njoro, but stooled exceptionally well. It may prove useful on this latter account as a crop for sheep-folding at the higher altitudes.

Kales, Cabbages and Rape.—Trials of these have been continued, to test how long they will persist. It is important to note that, at the first cutting, kales should be cut down to within three or four inches of the ground, so that an abundance of leaf growth may be obtained subsequently. The usual practice in Kenya of stripping the leaves from the stem has proved to be unsatisfactory, in that the plant will make little subsequent leaf growth.

Hubam Clover.—This again proved its value as a drought-resistant fodder crop.

In 1936, a randomized block variety trial of the most promising of the fodder crops was laid down. The crops used included:—

1. Songhor Napier grass,
2. Imported Napier grass,
3. Uba Cane,
4. Narrow Stem Kale,
5. Hubam Clover,
6. Lucerne.

The Hubam clover was the first to yield a cutting after planting, actually yielding 12.2 tons per acre of green matter four and a half months after sowing, planting 18 inches between the rows. The chief object of this experiment is to determine not only the total yield of these forage crops throughout the year, but their availability at seasons when they are likely to be most required, the number of cuttings likely to be obtained from them, and total yields of hay in the case of Hubam clover and lucerne.

C.—Molo.

Forage crops grown at this centre in 1935 were:—

Songhor Napier grass,
Oat and Vetch mixtures,
Ribaya Horse Beans,
White Mustard,
Giant Rape,
English Midsummer Rye.

The wet cold weather which prevailed at and after planting time affected all these crops adversely. The Songhor Napier grass grew slowly, and was severely affected by frost and cold. The oat and vetch mixtures were the most promising of these fodder crops tried, purple vetch and Biffen's oat proving a satisfactory mixture.

The *Brassica* crops (white mustard and giant rape) were completely destroyed by sawfly caterpillars, and the uncertain incidence of this infection makes their cultivation a difficult problem. Further, it has been found at Molo that in a successful year, when there has been no damage by sawfly, the *Brassica* crops tend to seed freely, and their eradication from the arable land is by no means easy, owing to the oily nature of the seeds and the length of time over which they may remain dormant. It would appear that of the *Brassica* crops the kales are likely to be the most satisfactory under these conditions.

English Midsummer Rye.—Although slow growing, this crop is likely to prove of value as a possible feed for sheep-folding, a practice which should be encouraged in this area.

These trials were continued in 1936, since many of the 1935 results were inconclusive. It is suggested that, when suitable crops have been proved, a trial should be laid down in 1937 to compare yields, as at Njoro.

Grassland Work in Nakuru District.

This work is carried out in collaboration with the Agricultural Officer in charge of Pasture Research.

A.—Rongai.

The trials consisted largely of a continuation of those started in 1934, when some 54 plots of grasses and legumes, both indigenous and exotic, were laid down; further plots were added in 1935. Drought conditions again prevailed through parts of the year, so that an excellent test has now been provided. The grasses which were outstandingly successful in withstanding drought were as follows:—

Indigenous *Cynodon* sp. (Star grass),
Amphilophis pertusa,
Cenchrus ciliaris (erect and creeping strains),
Melinis minutiflora (Molasses grass),
Setaria aurea (Golden Timothy),
Chloris gayana (Australian and Kitale strains).

A plot of woolly-finger grass (*Digitaria eriantha*) was established, and shows fair promise of drought resistance. Owing to its slow growth, however, it is as yet too early to say whether it is likely to prove of permanent value in this area. It would appear from the results obtained to date that there are no grasses, with the possible exception of Australian Rhodes grass, which are likely to be an improvement on the local indigenous star grass, when palatability, bulk of herbage produced, and drought resistance are all taken into account. Grasses tried at Rongai which had not been previously grown on the plots included the following:—

Ehrharta calycina,
Panicum antidotale,
Bromus marginatus,
Western Wolth's Rye grass.

Leguminous Pasture Plants.—Trials of these have yielded disappointing results; the local indigenous clover, *Trifolium Johnstonii,* being the most promising. Growth of *Lespedezas* and *Medicago denticulatum* was very poor.

As a result of the grassland work at Rongai, it was decided that there was a need for experiments on the best methods of rejuvenation of grassland which has become overgrazed in such an area. A large-scale experiment has therefore been laid down on Mr. W. G. Sewall's farm near Njoro, where the herbage is similar to that of the Rongai Valley and the rainfall uncertain. This experiment comprises such remedial measures as cultivation by disking, disking and ploughing, by harrowing, and also by re-seeding with exotic grasses. The experiment has shown that it is difficult to obtain satisfactory results under these dry conditions unless the land has been ploughed. The germination of seeds on land which had only been disked and harrowed was poor. The rejuvenating effect of cultivation on the indigenous herbage was most marked, particularly with indigenous *Cynodon* sp. Australian Rhodes grass and *Paspalum dilatatum* were sown, both alone and in mixtures together. Australian Rhodes grass has proved the more satisfactory, since *Paspalum* did not compete satisfactorily with the indigenous volunteer grasses.

These trials were continued in 1936. In addition, a four-acre piece of overgrazed grassland was obtained from Mr. J. E. Wolryche Whitmore at Rongai, and ploughed up, the purpose being to establish the most successful of these grasses. Plots of Australian Rhodes have already been sown, and show promise, and these will be grazed when ready. It has not been possible to complete the planting programme over this area in 1936, owing to the failure of the July rains, but it is proposed in 1937 to plant the whole of this area with indigenous and exotic grasses which have proved themselves suitable to the district.

The marked palatability of Australian Rhodes grass to cattle has proved itself in 1936 on the grazing plots on Mr. Sewall's farm, where the plots containing Australian Rhodes grass have been selected in preference to the indigenous herbage.

B.—Njoro.

In addition to some 99 trial plots of grasses and clovers, dating from 1934, two additional grasses were tried in 1935, namely, *Digitaria eriantha* and *Panicum antidotale.* Both of these show fair promise, but growth has been slow owing to the dry conditions prevailing, and results are not yet definite.

The chief work has consisted of laying down acre blocks of the grasses that have

proved most successful at Njoro for trial under grazing conditions. The control in this experiment is arable land which has been allowed to revert naturally to grass and already a fair grass cover has been made, composed largely of *Cynodon* sp., Kikuyu grass, indigenous Rhodes grass, *T. Johnstonii*, and *Indigofera* sp.

The grasses being tried on the large-scale grass plots are Australian Rhodes, *Paspalum dilatatum*, *Phalaris tuberosa*. Leguminous plants included in the mixtures are lucerne and Korean *lespedeza*. The latter does not show much promise. An excellent stand of the grasses has been obtained. It was found that broadcasting is preferable to drilling the seed, but heavy rolling is essential to obtain a good stand. It is intended to graze the plots in the near future and to keep accurate records of number of grazing days provided for the cattle.

The earlier work on the trials of English grasses showed that they all suffer in varying degree from the relatively high evaporation, and their use in this area is not likely to be practicable. These observations were all confirmed in 1935.

Some of the grasses obtained from Kitale showed fair promise at Njoro, namely:—

Golden Timothy (*Setaria aurea*).
Molasses grass (*Melinis minutiflora*).
Panicum maximum.

With the possible exception of *P. maximum* and Molasses grass, however, it is definite that these grasses do not produce more bulk than those already being tried. Since, furthermore, they are of a fibrous nature, they are probably not worth extended trial. *Panicum maximum* is worth further trial as a hay and grazing grass at Njoro.

Observations were continued on the large-scale grazing plots on the veldt, and the increase of the *Pennisetum schimperi* noted. Pasture improvement in this very restricted area would not appear to be along the lines of intensive grazing of the veldt, but would appear to depend more on sown-down mixtures and the natural reversion of arable lands.

The success of the large-scale grass plots has been demonstrated in 1936, when the stock-carrying capacity of the Australian Rhodes grass and Australian Rhodes grass and Paspalum mixture proved to be very high: actual figures will be available later. These grasses are being tried in comparison with natural reversion. The herbage on the plot which has reverted naturally to grass is of good quality, containing a high percentage of indigenous white clover and stoloniferous grasses, such as *Cynodon* sp. and *Digitaria* sp. The cattle, when allowed to graze selectively over the whole area, proceed immediately to the naturally reverted plot, and afterwards to the Australian Rhodes grass. The *Phalaris tuberosa* has not proved as successful at this altitude as the other grasses, although in mixture with Australian Rhodes it has held its own well. In pure culture it does not form a good enough bottom to the herbage. The *lespedeza* has died out in the mixtures, and the lucerne is persisting with some difficulty in competition with Australian Rhodes grass. Based on the results obtained from these experiments, an experiment in the recuperation of arable land was laid down early in 1936 on Njoro River Farm, by kind permission of Mr. M. D. Sullivan. A site of five acres was chosen, on which the maize last year yielded very badly, the land being worn out through continuous cropping. The area has been fenced into five-acre paddocks, and the following treatments applied:—

1. Maize planted continuously year after year.
2. Natural reversion of grass without grazing.
3. Natural reversion of grass with grazing and cutting.
4. Australian Rhodes grass sown down with lucerne.
5. Star grass planted from runners, Australian Rhodes grass sown from seed, and lucerne.

Results to date indicate that the practice of planting Star grass, *Cynodon* sp., from runners, together with Australian Rhodes grass seed, is likely to yield an excellent herbage. Further, that, provided no stoloniferous weeds are present, grasses can be established from seed on arable land, without any hand weeding, but simply by the judicious use of the mower to control the growth of annual weeds (which, in 1936, were exceptionally heavy). The Australian Rhodes and Star grass mixture plot was ready to graze approximately six months after planting. As each plot is fenced separately, it will be possible to keep accurate grazing results over these areas. After a period of three to four years, part of the area will be ploughed up and cropped with maize to test the recuperative effect on the land.

C.—Molo.

The grass work in this area has consisted mainly of large-scale trials of the English grasses under grazing conditions. In addition to these, two large-scale plots of the two most successful Australian grasses, *Phalaris tuberosa* and *Bromus marginatus*, were laid down.

The English grasses which have been tried out were Italian and Perennial Ryegrass, Cocksfoot, and Danish Meadow Fescue. These were selectively grazed during the year by dairy stock, and observations made as to the number of cattle-days of grazing. The cattle showed a preference for the Italian and Perennial Ryegrasses, as opposed to the Cocksfoot and Danish Meadow Fescue. Birdsfoot trefoil persisted fairly well in the pastures throughout the year, but the vetch which was planted to provide a legume died out completely. There was a considerable incursion of *T. Johnstonii* into the pastures. Results to date show that the English grasses have kept out Kikuyu grass remarkably well, but it will be interesting to see whether this obtains in succeeding years.

The establishment of grasses on the poorer soils in the area was also attempted successfully, in particular with respect to Western Wolth's Ryegrass, Cocksfoot, and *Phalaris tuberosa*. The grasses are at present in the young stage, and it is not possible to determine how far they will be successful. Indications to date are promising.

Continued observations have been made on the small grass and clover plots, and as a result a large number have been discarded. The imported clovers have shown themselves to be short-lived, and to die out rapidly even under the favourable conditions existing on a small plot.

Several new grasses and legumes were tried at Molo in 1935. These were as follows:—

Paspalum dilatatum,
Australian Rhodes grass,
Kitale Rhodes grass,
Panicum antidotale,
Cynodon sp. (Star grass),
Panicum maximum,
Sainfoin.

The wet cold conditions prevailing at Molo in 1935 were not favourable to the growth of the grasses. Australian and Kitale Rhodes and *Paspalum dilatatum* grew slowly, and had not covered the ground by the end of the year. With the exception of *Panicum maximum*, of

which a fair stand was obtained, the remainder were a failure. Sainfoin made fair growth in spite of the unfavourable conditions, and is worth further trial at Molo.

Further observations made on these grasses in 1936 showed that, in spite of the fact that they were slow to establish, *Paspalum dilatatum* and Australian Rhodes grass were subsequently successful; in particular *Paspalum. Panicum maximum* also made excellent growth, and showed promise as a hay grass, but it appears to be very susceptible to frost damage. A frost experienced in July caused all the foliage to dry off.

As a result of observations carried out in 1935, large-scale grazing plots of suitable mixtures of the English grasses were sown in 1936 in order to find a mixture which will form a complete bottom or sward and give plenty of bulk in addition. Unfortunately, it has not been possible to obtain any seed of *Medicago denticulatum,* which has up to date proved the most successful legume for pasture mixtures in this area. A large grazing plot of Australian Rhodes grass was also sown.

Phalaris tuberosa has proved its value under actual grazing conditions in 1936, and appears also to be very palatable to cattle under these conditions. The growth made has been much superior to that of any other grass hitherto tried, and it has been used as a constituent of the mixtures sown down in 1936.

Wheat: "Take-all" Experiment.

A rotation experiment was laid down in 1936 on Messrs. Sayers Bros.' farm on land on which the wheat crop failed completely in 1935 on account of this disease. The experiment embodies possible arable rotations, in addition to the best means of establishing natural grazing on "take-all" infected lands. This experiment will of course be continued over a period of years.

In addition, another "take-all" experiment, carried out in conjunction with the Plant Pathologist on the same farm, has been continued from 1934, when English and indigenous grasses were planted on badly infected "take-all" land, in order to determine which, if any, of these were carriers of the disease. It was originally considered that a two years' test would be sufficient; but since considerable difficulty was experienced in establishing the indigenous grasses, it has been decided not to plant wheat on these plots till 1937.

Grassland Manurial Experiment at Molo.

(*Altitude,* 8,400 *feet.*)

This experiment was laid down early in 1935, and consisted of the application of lime, salt, phosphate, potash and nitrogen. No results were obtained in 1935, either with respect to constitution of the herbage or bulk of the herbage obtained. A slight stimulation after rains, due to nitrogen, was, however, observed. Heavier applications of the fertilizers were made in 1936, the rates applied being as follows:—

Sulphate of Ammonia ...	200 lb.
Sulphate of Potash ...	280 lb.
Superphosphate ...	400 lb.

No marked results were obtained so far this year, except that again a slightly darker colour, due to nitrogen, was observed.

Fertilizer Experiment on Kikuyu Grass.

A fertilizer and manurial experiment was laid down on a Kikuyu grass paddock of low productivity at Njoro in 1936, and the following treatments applied:—

1. Sulphate of Ammonia: 224 lb. per acre.
2. Sulphate of Potash: 112 lb. per acre.
3. Superphosphate: 336 lb. per acre.
4. Guano: 560 lb. per acre.
5. Complete fertilizers: 560 lb. per acre.
6. Boma manure: 30 tons per acre.
7. Chaff and straw cavings: Surface covered to depth of 2½ inches.

It is hoped that it will be possible to tell by this experiment what is the best means of increasing the productivity of Kikuyu grass. If, as anticipated, the organic matter supplied by *boma* manure proves beneficial, it will be necessary to find out what is the optimum rate of application per acre to secure a high return. It is possible that humus can be supplied simply by the application of material such as chaff and cavings which will decompose and become slowly available.

Windbreaks and Shade Trees.

Demonstration windbreaks have been planted at all three centres (Njoro, Molo and Rongai) in 1936. The object of these is to lessen the evaporation during the dry season, to provide shelter for cattle and stock, and to lessen the effects of the wind erosion and the parching effects of winds. At each centre, five different combinations of tree species recommended by the Forest Department have been planted, and the growth at Njoro and Molo has been satisfactory. At Rongai, indications have been obtained as to the species which are most easily established in the dry season.

At Njoro, demonstrations of shade trees planted in clumps have been laid down. It is most essential, particularly in cases where old reverted arable lands are being used (from which the natural tree cover has been removed), that adequate shade should be provided for stock during the heat of the day. Suitable tree species, recommended by the Forest Department, are now under trial.

Review

All About the Soya Bean, by George Douglas Gray; John Bale, Sons & Danielsson, Ltd., London, pp. ix + 140, with 7 illustrations; with an introductory chapter by James L. North; 7/6d. net.

The author spent a number of years in China as a medical officer, and writes with authority about the uses of the Soy or Soya bean. When one has read the book and learnt how important the bean is as a foodstuff and an oil plant, and the many by-products for which the plant can be used agriculturally and industrially, one wonders why the Soya bean is not grown more extensively.

The Soya bean is indigenous to north-eastern Asia, and not to India, the Philippine Islands, Malaya, Australia and Africa, as stated by the author, although it has been introduced and cultivated in these countries with more or less success.

The bean, to reach maturity, requires a climate capable of ripening maize, and Mr. North, late Curator of the Royal Botanic Gardens, Regents Park, London, describes his years of experimentation before he obtained a variety which could be grown in East Anglia with success.

The book should be read by those who are interested in the Soya bean. Those who propose to take up its cultivation should remember, as Mr. North points out, it is estimated there are more than three thousand varieties under cultivation in China and adjacent countries, and that more than two thousand were introduced and tried out, over a long period, in the United States of America. Of these, only about forty have proved to be commercially successful. P.J.G.

Sheep: A Study in Agricultural Evolution

By V. LIVERSAGE, *B.Sc., M.S. (Wis.), N.D.A., Agricultural Economist, Agricultural Department, Kenya Colony.*

HISTORICAL.

The history of the sheep under domestication reaches back as far as the Neolithic period, and though scant information as to its importance during that period is available, in subsequent ages the sheep has played a great part in human economy. It was one of the most important domestic animals among the early civilizations of Asia Minor, and references to it abound in the old Hebrew writings. Among the early civilized communities it served a variety of purposes, including among them the provision of wool for clothing, skin for tents, milk, cheese, butter, etc. Leather and tallow are also among important products derived from this useful animal.

Among nomadic races the sheep proved especially useful. The variety of its products and the fact that it could be herded in large flocks and driven considerable distances must have contributed in no small degree to the estimation in which it was held by migratory peoples.

Within the period of written history, sheep have played a special role in the progress of civilization. In this connection the greater importance must be ascribed to the wool. Readers of English history are familiar with the spread of weaving from the Continent to England, the planting of elements of continental craftsmanship and culture in England, and the profound effects on native life and economy that ensued. Wool again played an imporant part in the progress of the Industrial Revolution, raw wool being transported from areas of production to the new centres of industrial activity, whence woven fabrics were distributed throughout the world. Coincident with this development was the recession of the margin of cultivation into large tracts hitherto unpeopled or traversed only by primitive races. Into these vast untenanted areas penetrated the pastoralist with his great flocks of meagre but hardy wool-bearing sheep. Sheep, as it were, formed the vanguard of civilization as it pushed further and further afield.

To-day the sheep is important by reason of its two main joint-products, mutton and wool. As a source of flesh meat, its development is relatively recent. In ancient times the flesh of the sheep was not greatly esteemed. Many wandering tribes in the East preferred the flesh of the horse and camel to that of the sheep, and the latter is by no means popular with many races even to-day.

England is a notable exception, and yet even in England it was until the pioneer work of the improvers of the eighteenth century that mutton began to take its present place as a popular article of diet. Previous to the work of Bakewell and others the sheep had been raised mainly for the sake of its wool.

The wool, skins and tallow became valued by-products, and a considerable trade arose in these commodities. The importance of tallow in earlier years was considerable, and before the development of refrigeration no other means, except salting, was available for disposing of the body parts in a distant market.

In parts of Central Europe there still lingers a system under which small flocks of sheep are kept on peasant holdings mainly for the sake of their milk, which is converted into cheese. The young animals may be killed for mutton and in

some cases also for their pelts.(1) The East Friesland milk sheep is said to be capable of giving up to 100 gallons of milk per annum on good pasture.(2)

The rise of sheep breeding primarily for mutton came in Europe with the live stock improvement of the eighteenth century. Some international trade in fresh killed mutton developed between countries at no great distance from each other, and live sheep were transported for quite long distances. Live animals were imported into Britain from places as far distant as Argentina and the United States. With the introduction of refrigeration about 1880, the market for mutton soon became world-wide, and vast quantities are produced to-day in areas formerly tenanted only by the wool and tallow variety of sheep.

The world sheep population, as far as can be ascertained, approximated to some 680 millions in 1930. Of these, South America and Australasia together claimed about 35 per cent, Europe (ex Russia) 18 per cent, North America 8 per cent, and the Union of South Africa 6.6 per cent. These areas together constitute the only parts of the world which are of much present importance in international trade in sheep products. For the other areas, statistics must be taken as little more than rough approximations. But since a large proportion of the sheep kept in Asia and Africa are not conspicuous for either wool or mutton qualities, and satisfy merely a local demand, these areas do not assume any great importance at the present day, and may be largely dismissed from present consideration.

As far as mutton is concerned, it will be seen from Fig. 1 that the areas of surplus production are entirely in the southern hemisphere, while of deficit areas the United Kingdom stands almost alone.

As far as wool is concerned, the exporting countries are again almost confined to the southern hemisphere, while the leading industrial countries of Europe, together with the United States of America and Japan, share in the corresponding importations.

The territorial distribution of sheep is determined by two interacting sets of relations. On the one hand there is the relation between the physical characteristics of sheep and their physical environment. Arising out of this are economic relations which determine the place of sheep in world agriculture.

Physical Factors.

Sheep are well adapted to living on short herbage of poor quality. They can thrive on herbage so short that other animals cannot bite it off. They are relatively independent of water supplies. They can graze on steep slopes which are not adapted to grazing by bovine stock. They are economical of labour; large flocks can be run under the care of a shepherd, and the herding instincts—of the Merino type in particular—facilitate this method of management in infenced ranges. They can be driven for long distances without grazing.

These characteristics render them well adapted to dry and rugged regions of sparse population, and they are to be found in large numbers on tracts of land which are below the margin of profitable arable cultivation, and too poor and hilly to support bovine stock. Certain types find a natural habitat on the arid and semi-arid plains of Australia, South America, the United States and South Africa. The lower mountains and hills, as those in the British Isles and in the Mediterranean region of Europe, also support large numbers. In these marginal areas sheep husbandry takes the form of a more

WORLD TRADE IN SHEEP PRODUCTS, 1930 (IN THOUSANDS OF Lb.)

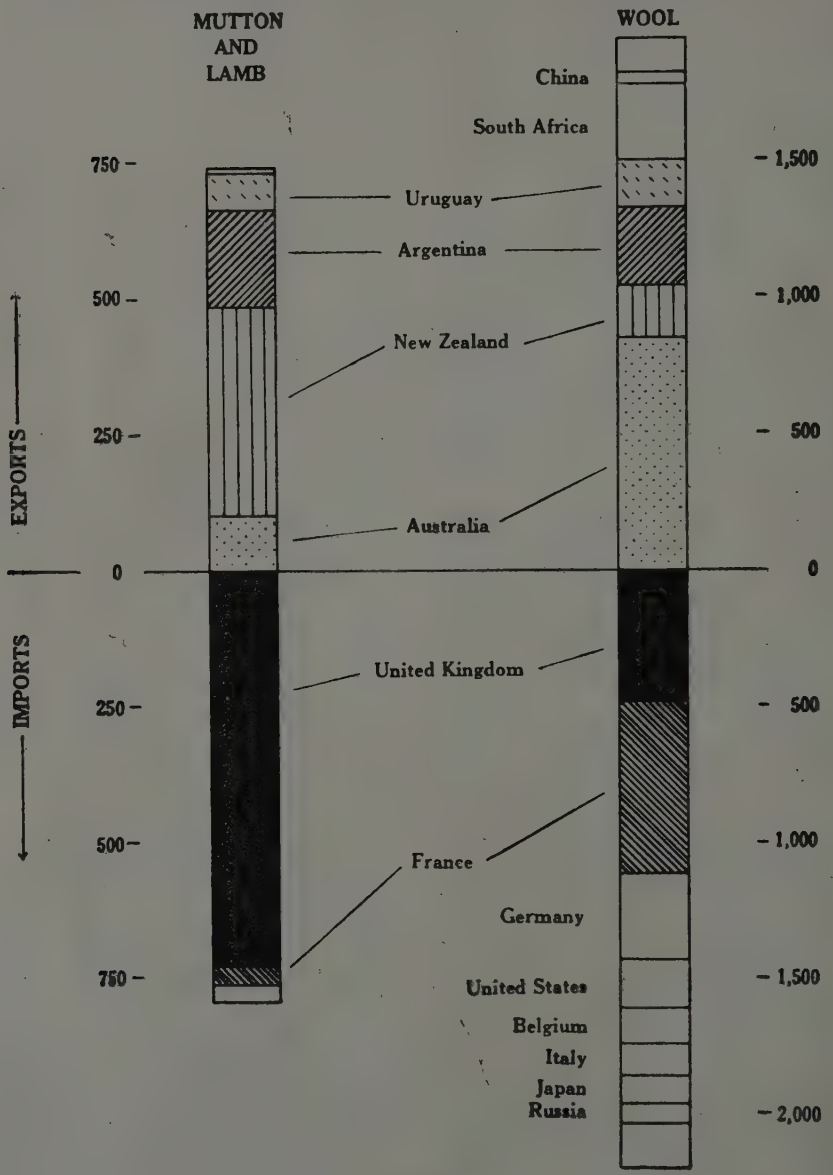

FIG. 1

or less specialized occupation. Within comparatively recent times sheep have accompanied civilized man into formerly untouched storehouses of natural wealth in Australia, New Zealand, the Argentine, the United States, and South Africa.

All types of sheep do not serve the same purposes, nor possess the same physical characters. On the one hand, there is the Merino type, producing fine wool but slow-maturing and of little value for production of mutton. At the other extreme there is the long-wool, early maturing mutton type, the wool of which is a mere by-product in relative importance.

The merino type has a well-developed herding instinct, and grazes in massed formation, being thus adapted to grazing on open ranges. It thrives under arid conditions. The special quality of the wool shows deterioration under softer conditions, and the animals themselves are more subject to disease.

Between these two types there are the crossbreds, produced by crossing merinos with long-wool breeds. These combine wool and mutton qualities to a greater or less extent, and are similarly intermediate in the place they occupy in agricultural systems.

Certain other types, such as the Asian and African hair sheep and the German milk sheep, merit no further notice in the present study.

Transhumance.

The place of sheep in world agriculture has been influenced by a peculiar quality, their adaptation to the system known as transhumance. Sheep were and still are important in the nomadic stage of civilization. "Nomadic herding is the dominant and almost exclusive mode of agricultural land occupance in a vast territory in Asia and Africa that makes up perhaps one-tenth of the earth's total land surface. . . . Sheep are admirably suited to living in these lands of scanty forage and restricted water supply, and they yield wool, meat, milk and skins, all of which are very useful to their owners . . . seasonal migration is a characteristic of nomadic herding, as is the movement of the encampment every few weeks to fresh grazing grounds. . . ."(3)

It is but a short step from the nomadic system to one whereby the sheep travel between two areas as the sun travels north and south during the year. In the neighbourhood of mountain pastures a yearly migration between lowland and plain often takes place. This form of movement was developed at an early stage in the history of sheep husbandry. Thus on the Roman campagna in the fifteenth century a safe-conduct of the Curia which Boniface IV gave to the Apennine shepherds who brought their flocks to winter on the campagna provides a glimpse of the system.(4) In Naples: "As early as 1155 William de Hanteville made a special constitution in favour of the shepherds of the Apulian plain . . . and a long series of usurpations and reinstatements affected the paths across cultivated lands which led wandering flocks to and from these Apulian pasturages."(5) In Spain there existed a notion that the merino sheep would not grow fine wool unless they were driven between low and high altitudes and thus kept in an even temperature throughout the year. Under the influence of the historic Spanish shepherds' association, the *Mesta,* helped by the fact that many persons in high places were directly interested in the profitable business of wool growing, a code of regulations, or rather privileges, was drawn up governing the "transhumantes". The great flocks were herded to the mountains in the spring and back to the plains in the autumn. They would travel "journeys as

long as 400 miles at the rate of twelve miles a day in spring, when the lambs were about six weeks old, and underwent the same journey back again in the autumn."(5)

In New Zealand at the present day, "sheep are fed upon the mountain pastures in summer, while in winter they are driven down to the lower slopes of the hills, sufficient fodder being grown in the flat valley bottoms to maintain them in seasons of exceptional severity."(6) "In Italy, Spain, Provence and Thessaly, vast flocks of sheep driven by their shepherds pass the summer on the lofty plateaus or in the high mountain regions, and in the winter come down toward the plains, where they crop either the natural grasses or the dried stalks left in the fields after harvest."(7) In the high Asiatic mountains, "between the glaciers and the icefields in protected vales and parks, alpine meadows provide food for the stock which the nomadic residents of the lower slopes or the surrounding grasslands bring seasonally to pasture on the rich, nutritious grasses of the high alps."(8) "In western United States . . . migration is practised in search of winter forage, when the mountains have become inhospitable. In central Chile, the low grazing lands become parched during the rainless summer, and force the graziers and their flocks to the rainier mountain ranges. In the Argentine, just across the lofty Andes, as the plains become drenched with rain, the herders drive their bleating droves to the mountains to enable them to escape the humid summer heat and the insect pests that prevail at this time, and also to permit the ranges to recuperate." In the Salt Lake region, " . . . The rainfall in the mountains at elevations ranging from 7,500 to 8,700 feet is about ten times the amount received on the desert 75 miles to the west. . . . These arid pastures furnish sustenance to thousands of animals from November to May. . . . As the snow melts on the desert the water supply disappears, and the animals follow the retreating snow line up into the mountains . . . they begin working slowly towards the alpine meadows, which they reach in September. . . . About September 30th the breeding stock . . . are driven towards the irrigated valleys or desert ranges for winter . . . the sheep require from one to three weeks to trail from the mountains to the desert, and even more to return, because they frequently wander as far as 250 miles. . . . Thus the animals occupy in alternation two complementary zones, each of which can support them for a part of the year only."(9)

In countries such as Great Britain the progression of sheep, during their lifetime, from the breeding farms on the hills and moors to the lowland farms on which they are finished on turnips, might be regarded as a special form of transhumance, as also the practice of sending gimmers from the moorlands to the lowland farms for wintering.

Wool.

In connection with the physical basis of sheep husbandry mention should be made of the fact that wool can be transported over long distances without deterioration. Sheep production for wool can therefore be carried on under conditions such as those obtaining in Australia in the early days, when "the wool came down to Sydney in bullock drays. . . . In many cases the wool had been months coming down from the stations."(5) Add that wool is light in weight in proportion to its value, and it is seen that wool production is suited to areas remote from markets.

Economic Factors.

The different types of sheep have their special place in world agriculture, which

will be best understood in the light of the general territorial structure of agriculture. The two main influences affecting their distribution are the nature of the land and its situation with respect to markets. The theory on the latter subject was first developed by Von Thuenen. In his deductive study, *The Isolated State,* published early in the nineteenth century, Von Thuenen supposed a city set in complete isolation in the midst of a plain of which the soil was of unvarying fertility. The city represented the only market available for the products of the surrounding plain, and transport was supposed to be in a radial direction. Under these circumstances agriculture would shape itself as follows:

In the vicinity of the city such products would be raised as have a great weight or bulk in proportion to their value, or are of a perishable nature. The whole area would in fact take on a concentric arrangement with the city as centre. This arrangement is not well understood in detail, but the principles are quite clear. Near the city the products raised are so valuable and the land takes on so high a value that it transcends the necessity for a rotation of crops. On the periphery of the area the practice of crop rotation thins off for the opposite season, and the outermost zone is devoted to ranching.

The ranching zone may be further subdivided. The periphery is occupied by sheep kept for their wool alone, mutton being so far neglected as not even to appear as a by-product. This system represents the extreme of extensity, and is only to be found in the most infertile and least accessible areas. Where contact with the market is more direct and the conditions more amenable we find the production of mutton added to that of wool. Whereas in the outermost zone the fine-wool types are kept exclusively, the merino becomes displaced in the next zone by the long-wool cross.

As we progress geographically towards the centre of the market area, mutton production increases in importance relatively to that of wool. Finally, there is reached a stage where sheep come into competition with cattle or grain and decline in importance. Where they persist they do so as a component part of a mixed farming system, and with rare exceptions consist entirely of coarse-woolled mutton types.

It is necessary to follow Von Thuenen's reasoning a stage further. Land nearer the city enjoys a double advantage; not only is the cost of transport lower on the same commodities, but some commodities, such as very perishable goods, can be marketed only from the neighbourhood of the city, as physical reasons prevent their carriage over greater distances. These advantages become expressed as differences in the market value or rent of the land. It becomes necessary to devote the proximal zones to the higher-value uses.

In fact, instead of distance from the market we can consider the value of land as the dominant influence in shaping the development of agricultural systems. The theory then takes account of differences in the quality of land simultaneously with differences in market accessibility, the two factors operating in much the same manner.

It is obvious that the factor of land value can only operate within an area the parts of which are in effective economic contact, and this does not apply to all parts of the world. Sociological factors isolate large areas from a world market economy. Thus large areas in Central Asia and in Africa, which are ideally suited to fine-wool sheep, support, instead, the hairy type because their owners prefer or know no better than to follow ancient custom rather than to engage in the pur-

suit of material wealth. The present consideration may be confined to Europe, North and South America, South Africa, and Australasia.

Geographical Aspect.

The principles adumbrated by Von Thuenen find expression in both a geographical and a historical phase. Taking first the geographical phase, we find sheep taking a relatively more important place in the southern hemisphere, while the chief concentrations of population in which international division of labour is developed lie in the northern. The typically merino area, where large flocks are run on open ranges and where wool is almost exclusively the object comprise chiefly the remoter and drier parts of Australia, the "back blocks" of New Zealand, the arid plateau of South Africa, the wilds of Patagonia, and the Andean grazings of Chile and Peru. In Europe, the only places where such persist are the dry, warm hillsides of the Mediterranean countries.

As the fertility of the land improves and the distance from markets decreases, mutton production increases relatively to that of wool. The greater part of New Zealand, the far west of the United States, the pampa of the Argentine, and certain parts of Australia, are now in a dual purpose stage.

The countries of north-western Europe and the north-eastern portions of the United States, which are in relative proximity to large industrial populations, do not support many sheep. Such as are kept are predominantly of the mutton types. The British Isles is an exception in that it is still one of the densest areas of sheep population in the world; this is accounted for partly by its excellent grazing land, partly by the large area of hilly land of low value in the northern and western portions of Great Britain, and partly by the place which sheep have retained in mixed farming systems.

Numerous examples could be adduced to show the inverse correlation of sheep husbandry and land values. In England and Wales sheep raising is more important in the districts where the greater part of the rough grazings are found, and the average rent per acre of the rough grazings in England and Wales is given as 4s. 6d., which may be compared with an average of 31s. for agricultural land exclusive of rough grazings.(10)

In the United States, the range states of the Great Plains and the western mountains, which now form the chief sheep-raising area, are characterized by lower land values than other parts of the country in the same latitudes.

TABLE I

Land Value in the United States (Exclusive of the value of buildings) 1927.

From the United States Department of Agriculture Yearbook, 1927

Division	Average Value of land per acre $	Typical Farming System
New England ..	26·10	Milk production
Middle Atlantic ..	35·54	Mild production
East North Central	70·68	Butter, Cheese, Cereals, Milk
West North Central	53·63	Cereals, Cattle and Pigs
Mountain ..	13·96	Ranching—mainly Sheep

The figures in the mountain division include, at the one extreme, a value of $38.27 for Idaho, and at the other extreme one of $7.94 for New Mexico, $7.94 for Wyoming, and $11.90 for Montana. In the three last mentioned states the typical form of sheep ranching is pursued, but in Idaho, where the higher values prevail, sheep husbandry is of a

more intensive character and "very nearly half the Idaho sheep raisers are now engaged in early lamb production. . . . The Idaho flockmasters have come to depend more and more on winter feeding."(11)

Historical Phase.

It is in the historical aspect that the principle finds its clearest illustration. As the population of the market area increases, the standard of living rises and secondary industries become more important, so the value of land rises. It becomes necessary to increase production at the intensive and the extensive margins; that is to say that the intensity of cultivation rises on the inner zones and the market area becomes extended. This latter effect is accentuated by improvements in transportation and, further, by the continued drift of population away from the country into the large urban centres. The result is that ranching systems are constantly under the necessity of seeking fresh areas. Sheep husbandry is constantly being shifted outwards towards the remoter and less developed parts of the world. The vanguard in this territorial advance is formed by the fine-wool sheep. They are followed by dual purpose types, and these in their turn by mutton breeds. Sheep as a whole are displaced by cattle, cereal-growing, mixed farming, or dairying, according to the local circumstances.

In some circumstances it appears that cattle are the first invaders of the waste, either because the herbage is too coarse for sheep until it has been eaten down by cattle, or because cattle are better "rustlers", or because they can travel farther. The picturesque cowboy was a familiar figure in the western states of America long before the coming of the shepherd with his fine-wool flocks. In the Northern Territory of Australia "most of the grazing land is occupied by cattle, because the high labour costs and the difficulty of transporting wool have driven out the sheepmen, cattle being able to travel many times further than sheep to reach a market. . . . In January, 1931, sixty thousand cattle were reported in a drive from Northern Territory southward across the continent. In the drive of 1921 seventy-three thousand made the journey, taking two years."(12)

Nevertheless, wool production forms the first important stage of settled husbandry. Hides and tallow are secondary products. The carcasses of cast sheep have sometimes even been left to be devoured by carnivorous animals and birds, or used as fuel.

The course of evolution in farming systems is abundantly exemplified. In the following paragraphs some examples are given by way of illustrating the principle and also of showing the state of sheep husbandry in some important areas. For the most part, the historical treatment is confined to the period from 1870 to 1930, for the reason that little statistical information is available for any earlier period and that since 1930 the international division of labour, on which the natural evolution of agriculture depends, has been so largely interrupted by trade restrictions.

Australia.

In Australia, in 1850, the total sheep population was estimated at just short of sixteen millions. By 1860 the numbers had increased to twenty millions. The stocks increased at a rapid rate until 1891, when a total of one hundred and six millions was reached. At this time it became apparent that the ranges were becoming overstocked in their unimproved and badly watered state.

Following 1894, a succession of unfavourable seasons caused a severe decline in the sheep of the Commonwealth. The worst was that of 1902, in which the

numbers decreased by 25 per cent from the previous year. By the end of 1902 they had shrunk to little over fifty millions. From that time onwards successive increases were registered, and the former high level was approached by 1911. Droughts in 1912 and 1914 again caused a reduction—of some twenty millions from the 1911 total of ninety millions—and since this time the trend, in spite of fluctuations, has been definitely upwards.

In the early days, wool, skins and tallow formed the sole objects of sheep husbandry in Australia, and attention was given primarily to the production of fine wool of the merino type. Meat ranked as a by-product of the wool. Some canning and manufacture of meat extracts was followed from about 1870 onwards. A change appeared in the trend of sheep-breeding from about 1882, occasioned by the development of refrigeration and its application to the transport and storage of mutton. Here Australian sheep-breeders found themselves confronted with the difficulty that their hardy, thin-shanked merino type was quite unsuitable for the high-class English trade in mutton. Three courses were open to them: they could give first place to either wool or mutton production, or they could attempt to combine the two. The returns

NUMBERS OF SHEEP IN IMPORTANT COUNTRIES, 1870–1930

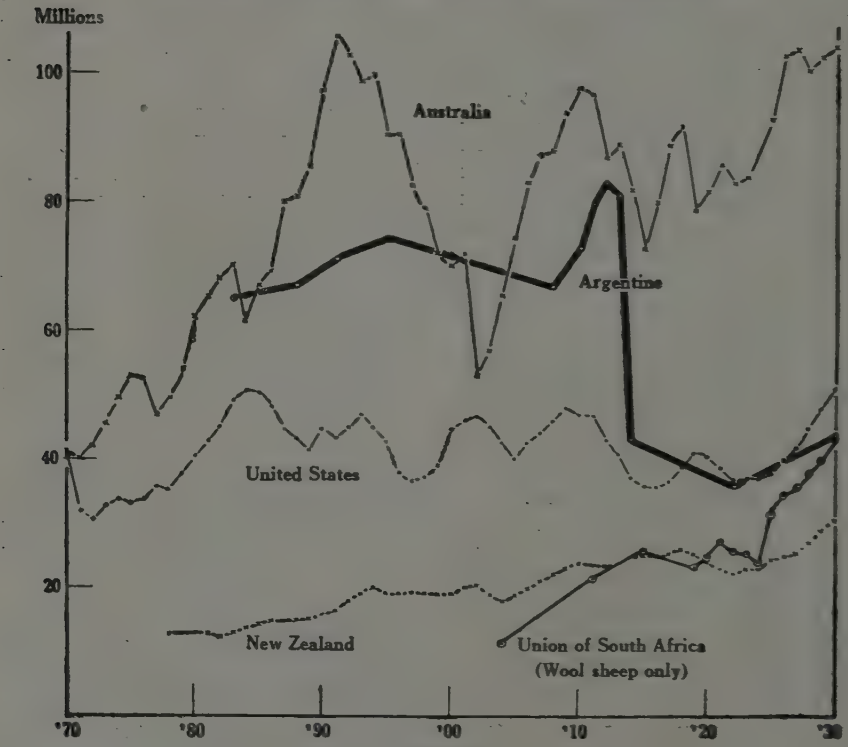

FIG. 2

from mutton were becoming increasingly attractive, and without this outlet the carcasses were an unremunerative by-product. But the land and climate in most areas were such as to favour wool production. Cross-breeding was not suitable for all circumstances, and entailed some reduction in quality, both of mutton and of wool, as compared with the pure types respectively. Consequently, wool production as a main object has maintained a predominant place in Australian stock farming, where such a preponderant portion of the land is as yet undeveloped. Nevertheless, there has been a definite movement in the direction of cross-breeding. About 1880 it is stated that only 3½ per cent of the sheep in New South Wales (which maintains a large proportion of the sheep in the Continent) were long-woolled or cross-bred, and during the "eighties" the proportion stood at about 2½ per cent. In 1893 it stood at 4.3 per cent, but by 1904 had risen to 8 per cent. English breeds, such as Lincolns, Romneys and Leicesters, were used for crossing on the Australian merinos. The Lincoln was by far the most popular for the purpose. In 1902 there were also almost half a million sheep of pure English breeds, including, besides those mentioned, some Shropshires, Southdowns, and Suffolks.(13)

The course of subsequent development is glimpsed in the fact that in 1912 the proportion of cross-bred wool produced in the Commonwealth was 18.6 per cent, and that in 1919-20 it had risen to 33.9 per cent. The accumulation of coarse wool after the Great War led to a return to merino, and the proportion of cross-bred wool fell from 33.9 in 1919-20 to 14.87 per cent in 1927-28, at about which point it has since remained.(14)

It has been claimed that the carrying capacity of Australia could be considerably increased by various measures of intensification, such as fencing, culture of drought-resisting plants, etc. In general, measures of intensification have not in fact proved to increase the sheep stocks, but rather to result in the increase of other kinds of stock and of cultivation at the expense of sheep. This may be illustrated by a comparison between Victoria and the adjacent state of New South Wales. The ratios of increase of cattle and sheep in the two states since 1870 have been: —

	Victoria.	*New South Wales.*
Cattle	2 ...	1⅞
Sheep	1½ ...	4

In the state of Victoria, more highly developed agriculturally, there has been a differential movement in favour of cattle, when compared with New South Wales. In the former state, intensification, though still accompanied by an increase in sheep, is tending to favour cattle breeding.

The sheep stocks of the various states in 1930 were as follows: —

New South Wales	53,366,000
Queensland	22,542,043
Victoria	16,477,995
South Australia	5,980,959
Western Australia	9,882,761
Tasmania	2,119,606
Northern Territory and F.C.T.	198,915
Total ...	110,568,279

In South Australia the area suited to sheep is limited, and no great expansion can be looked for. Tasmania is devoted mainly to breeding for stud purposes, and large commercial flocks are not characteristic; in fact, the number of sheep on the island has scarcely changed since the "sixties". The steadiest increase has been taking place in Western Australia.

New Zealand.

With a sheep population approximating to the numbers in Great Britain, New Zealand leads the world in the export of mutton, and takes fourth place in that of wool. Canterbury lamb is a commodity famous on the meat markets of England.

New Zealand is a country with a moist equable climate which favours the growth of a good class of pasture. Stock thrive in the open at all seasons of the year. The natural pasture has been much improved with the introduction of more productive strains of grasses and the use of phosphatic fertilizers. By 1878 there were thirteen million sheep in the Dominion, and by a regular progression these increased to upwards of thirty millions in 1930. Fluctuations in numbers have been very small, New Zealand not being subject to the periodic droughts which handicap the progress of sheep farming in some other important sheep-raising areas. Predatory animals are almost non-existent, and the most serious pest is the rabbit.

In the early days of sheep-breeding in New Zealand the merino was the breed relied upon, and with wool as the main product the carcasses of cast sheep were boiled down for tallow. As in the case of Australia, the development of refrigerated transport about 1882 altered all this. The mutton trade developed to such an extent that there are now 25 freezing works, capable of dealing with 120,000 sheep and lambs per day, in addition to cattle and pigs.

As in Australia, sheep-breeders were faced with a choice between the rival claims of mutton and wool. Unlike the majority in Australia, however, they decided generally in favour of the cross-bred. In the early days the English Leicester was the breed generally used for crossing with the merino, but later on the Lincoln was largely used. Systematic in-breeding between the merino and the cross-bred produced the Corriedale.

Latterly greater reliance has come to be placed on mutton types. Not only have blackfaced (Down) rams been used on the cross-bred ewes, but large numbers of pure English stocks are being kept. The Romney now leads all breeds in point of numbers among the sheep of distinctive type in the Dominion, being especially suited to the moist climate of North Island. The Southdown, too, is being increasingly used for early lamb production. The relative position of the various types in 1930 was as follows:—

Fine-wools	...	4 per cent.
Cross-breds	...	82 per cent.
Mutton breeds	...	14 per cent.

During recent years increasing attention has been paid to the production of lamb, with its quicker return to the pastoralist.

The total stock carried in New Zealand has shown a general increase. The area in grass has increased from twenty-eight to thirty-one million acres since the beginning of the present century, or by 11 per cent. In the same period the total stock carried, expressed on a common basis as sheep units (6 sheep = 1 head of cattle) has increased by no less than 69·7 per cent. The area of land returned as occupied is 28 per cent greater than at the beginning of the century, and it thus becomes evident that not only is the amount of land devoted to stock keeping increasing, but the land in use is being more heavily stocked. Furthermore, the production per unit of stock carried has increased some 37 per cent in the same period.(15)

This increase in production may be ascribed to several causes, including closer settlement, improvement of live stock and live stock management, increased use of fertilizers and greater resort to artificial forage crops.

While the total live stock of New Zealand has thus continued to increase, there has been a shift in the direction of dairying and cattle production, as will appear from the following figures:—

	Sheep.	*Dairy Cows.*	*All Cattle.*
1902 ...	20,342,000	381,000	1,361,000
1930 ...	30,841,000	1,440,000	3,766,000
Increase	52%	278%	177%

Thus, during the present century, sheep increased by 52 per cent, cattle of all kinds by 177 per cent, and dairy cows by no less than 278 per cent.

South America.

The southern half of South America bears some resemblance to Australia, in that it embraces large tracts of arid and semi-arid land subject to periodic droughts. It differs in including a much larger area of well-watered cultivable land producing coarse grass in its natural state.

The remote, undeveloped plains and uplands support a few large flocks of unimproved sheep producing little more than 1½ lb. of wool per fleece. Large areas towards the north are covered with dense forest, while the heights of the Andes rise far above the level of ordinary pastoral pursuits. The approximate numbers of sheep in the more important states are as follows:—

	Millions.
Argentine	44.4
Uruguay	20.5
Peru	11.2
Brazil	7.9
Chile	6.2
Bolivia	5.0

Only those in the Argentine and Uruguay play any important part in world trade in sheep products.

Argentine.

The pampa of the Argentine are extensive plains of uniform relief, covered with coarse grass. In Rio Grande do Sul and in Uruguay also there are vast areas of natural pasture, plentifully supplied with small streams. The area of pasture in the two latter areas is being extended by artificial establishment on "cut-over" land. The climate is relatively cool, and there is absence of a long dry season. Rainfall is, generally speaking, evenly distributed over the year. Droughts sometimes occur, particularly towards the interior, and may do very considerable damage. The worst on record occurred in 1914, when five million sheep perished in Uruguay and the Argentine flocks were reduced by almost 50 per cent. The damage was accentuated by the overstocked condition of the sheep pastures. On the pampa such troubles are being guarded against by the sinking of wells and erection of windmills. The water, however, is sometimes found to be saline. When success is attained, the resulting development tends to favour cattle rather than sheep. Locusts sometimes devastate parts of the continent.

About the middle of the last century, sheep husbandry in South America was mainly nomadic, and the main object—almost the only one—was wool production. The first shipment of wool to Europe was made in 1840, and from that time onwards an established trade developed, and merinos were bred to supply the wool markets of north-west Europe. The carcasses were of little value; mutton was never a popular article of diet with the South American people, and the sheep kept were never such as to stimulate a taste for it. They were often slain, the wool being pulled from the bodies and, after flaying, the rest left to the dogs and buzzards. Thousands were driven to brick kilns, slaughtered on the spot, and their bodies, stripped of the hide, flung into the furnaces to feed the fires. Others were boiled down for tallow.

From about 1860 the land became appropriated by individuals, and divided into large *estancias* enclosed with wire fences. Preserved meat establishments (*saladeros*) and meat extract factories began to provide an alternative outlet for some of the carcasses. These factories, however, dealt mainly with cattle, manufacturing the so-called "jerked beef". During that period the numbers of sheep increased but slowly, and comprised fine-wool types almost exclusively, apart from the unimproved ancient stock. The *estancia* stage was accompanied by improvement of the strains of sheep kept.

Two influences have participated in determining the subsequent course of sheep farming in South America. The first is the rise of the frozen mutton trade; the second the spread of crop cultivation and mixed farming.

As early as 1880 successful trial shipments of frozen mutton had been made to Europe. From 1883 onwards a regular trade developed, and early in the present century shipments from the Argentine to the United Kingdom alone reached 1½ million cwt.

This increase in mutton was not accompanied by a corresponding increase in the numbers of sheep. It was due to a change in the method of disposal of the carcasses, and in order to meet the new demand a change in the type of sheep was essential. Prior to 1890 merinos predominated; McIvor puts the proportion of cross-breds in 1891 at 10 per cent. For the new trade in mutton increased attention was given to crossing with long-woolled mutton breeds, and the Argentine was the leading customer of Great Britain for breeding stock. By 1903 cross-breds comprised about 70 per cent of the flocks.(16)

Mutton production has increased relatively to that of wool during late years, as the following export figures show:—(17)

	Mutton Exported. Million lb.	*Wool Exported. Million lb.*
1909 ...	146 ...	389
1930 ...	177 ...	297

On the semi-arid ranges remote from rail transport, production of fine wools is still the main object, but whereas this was once true of the fertile pampa, it is no longer so, and wool production as a sole or main object has been pushed farther and farther away from the more highly developed regions. On the pampa the substitution of dual purpose types for fine-wool sheep is now complete.

The other development referred to is the change from grazing to mixed farming which has been going on during the last half century. The fertile soil of the pampa has made this region one of the important grain-growing regions of the world. The following table shows the extent of the development which has occurred in this direction.

CROPS AND LIVE STOCK IN THE ARGENTINE (MILLIONS).

	1883.	1892.	1913.	1922.	1930.
Wheat, acres	0.6	3.2	16.2	16.2	20.6
Maize, acres	0.5	2.2	10.2	7.8	13.4
Lucerne, acres	0.3	1.6	—	19.5	13.8
Cattle, No.	—	22.0	30.8	37.0	32.2
Sheep, No.	65.0	75.0	81.4	36.2	44.4

The table shows a very considerable increase in the area under cereals and lucerne, and a general increase of cattle relative to sheep. The lucerne is used mainly for cattle grazing; sheep bite too close and eat the heart out of the plant. On the large *estancias* it is common for owners to lease a portion of their land to "colonists" operating on a crop-share basis. After a course of cereal-growing the land is sown down once more to lucerne.

URUGUAY.

In Uruguay also some progress has been made in the direction of mixed farming,

but so far there has been no tendency for crops and cattle to outstrip development of sheep farming. The opposite, in fact, has been the case.

CROPS AND LIVE STOCK IN URUGUAY.
(MILLIONS.)

	1894.	1913.	1930.
Wheat, acres ...	0.5	0.9	0.8
Maize, acres ...	0.3	0.6	0.4
Sheep, No. ...	12.8	11.5	20.6
Cattle, No. ...	5.4	7.8	7.1

THE UNITED STATES.

The United States maintains some fifty million sheep, a number which has shown only a moderate increase since 1870. Until 1910 the general trend in numbers evinced an upward tendency. A downward movement set in at that time, continuing with minor fluctuations until 1922, since when the fifty million mark has been passed.

Sheep were introduced into the United States as early as 1609. They became established with difficulty. Predatory animals, Indians and the severe winters combined to render their existence a precarious one. Trouble from carnivorous animals is still experienced. Losses to western flock owners "were formerly estimated to amount to from twenty million to thirty million dollars annually." (17)

By 1810 it is estimated that there were about seven million sheep in the United States. A domestic woollen industry established itself under the stimuli of anti-British legislation, protective duties, the Napoleonic wars, and the growth of cities. By 1840 there were nineteen million sheep in the country.

Up to 1860 may be taken as the wool-growing period, and the merino was the dominant type of sheep kept. After 1860 the industry may be said to have entered on the mutton period, though wool production has remained important. Slaughter became centralized in great "packing" establishments.

During later years the country has been on an import basis, especially as regards wool. Imports of mutton and lamb showed a tendency to increase in the two decades ending in 1930.

The United States exhibits a complete succession in the stages of intensity in sheep farming, though fine-wool sheep are now kept only in hilly sections in Ohio and neighbouring States. On the western ranges dual purpose cross-breds are run as a specialized ranching proposition; in the grain-growing and irrigation areas of the Middle West small farm flocks of mutton types are kept as an integral part of a mixed farming system, and persist also to some extent in the dairying areas of the east. Finally, as the most intensive stage, production of "hothouse lamb" is of importance near the large cities, and has assumed a prominent development in Idaho.

The mutton period has been marked by a change-over from merinos to dual purpose and mutton types. The geographical distribution of sheep has changed with the increase in population and greater industrial development, the change in general methods of land utilization and in the intensity of cultivation. In colonial days it was naturally confined to the eastern seaboard, and in 1840 all the sheep in the country were east of the Alleghanies. From 1850 onwards the eastern sheep farmers turned to the production of mutton, and wool production as a primary object moved farther west to the rough lands of Ohio and Michigan, and to areas where grain farming was not profitable at the low prices then prevailing. Simultaneously, dairying grew in importance in the east and competed successfully with sheep farming, though for a time mutton production persisted and many wethers

were fed during the winter for marketing in the spring.

As the grain area shifted farther west it took with it a system of farming in which the live stock element was supplied by cattle and pigs, sheep persisting only on the unlevel lands and as small flocks on mixed farms. The great grain-producing area of the Middle West now carries relatively few sheep, and the centre of the industry has shifted to the great semi-arid plains which skirt the eastern margin of the Rocky Mountains, where the sheep are kept on open range.

The Union of South Africa.

The Union of South Africa is one of the six areas of densest sheep population in the world. Its flocks number some 48 millions, a number rather less than half that in the whole continent of Africa.

The territory comprised within the Union consists largely of poor arid and semi-arid scrub lands. Prolonged droughts are common. Artificial water supply and transport arrangements are little developed.

It is not surprising therefore that wool production should be the main object of South African flockmasters. Of the forty million sheep in the Union, only four million are classified as of other than wool type. The merino is the dominant breed.

Sheep were first imported about 1654, when the Dutch East India Company sent out a selection of breeding stock. These were followed by some Spanish rams in 1689. In 1790 Colonel Gordon imported a number of merinos, some of which were afterwards shipped to Australia, and helped to found the present large flocks of wool-bearing sheep in the Commonwealth. The imported stock were used to grade up the native Cape sheep, which was a hairy, fat-tailed animal.(18) More recently importations have been made from Australia.

There has been a considerable increase in numbers of sheep in the Union Province since 1904, to which a sharp spurt during the period 1924-27 has in no small degree contributed. The increase has been entirely in wool sheep, as the following figures show:—

Number of Sheep in South Africa. (Millions.)

	Wool Sheep.	*Other Sheep.*	*Total.*
1904	... 11.8	... 4.5	... 16.3
1911	... 21.8	... 8.8	... 30.6
1921	... 36.0	... 4.1	... 40.1
1930	... 43.9	... 4.4	... 48.3

99 per cent of the wool exported from the Union to the United Kingdom is classified as merino.

The Continent of Europe.

Western and Central Europe, as far as the present subject is concerned, fall into two broads divisions. On the one hand is the north-western portion, a pasture, hay and dairy region. Over this area the contours are relatively uniform, the climate moist and temperate, and the grass of good quality. These natural factors, combined with the proximity of large centres of industrial activity, of high land values and intensive agriculture, make mutton the chief object in sheep husbandry, and wool becomes of comparatively little account. In England, the most highly industrialized of all these countries, all the sheep are of the mutton types.

On the other hand, there is the Mediterranean region, in which the climate is warm and in which a combination of semi-arid plains and steep slopes renders sheep husbandry well adapted to the prevailing conditions. The area is not highly industrialized, and in parts the people are semi-nomadic in habits. This area, comprising Spain, Italy, and the Balkan countries, is one of the densest areas of sheep population in the world. The sheep are mainly of the wool types.

Spain is noteworthy as the original home of the premier wool-bearing sheep, the merino, which has played a dominant part in the improvement of local types throughout a large part of the world.

In some European countries there persists a type of hardy native sheep used largely for milk production. These milk sheep, which form 34 per cent of the total sheep in Germany and 23 per cent in Hungary, are found mainly on the peasant holdings, and the milk is generally converted into cheese. The East Friesland milk sheep, it is said, "can be milked from 150 to 200 days in the year, with a yearly product of more than 1,000 lb., if on good pastures."(1) (2) Milk sheep are sometimes used for crossing for the production of early-maturing lambs, and sometimes the lambs are killed at a few days old and the pelts used as fur.

In the Mediterranean region sheep have shown a general increase. In Spain the numbers increased from 13.3 millions in 1891 to 19.3 millions in 1929, an increase of 45 per cent. In Portugal there was an increase from 2.9 millions in 1870 to 3.7 millions in 1925; in Italy from 8.6 millions in 1881 to 9.9 millions in 1930. The Balkan countries appear to have shown a similar tendency.

The countries forming the north-western portion of continental Europe illustrate the last stage in this geographical distribution and historical progression. Industrialization and intensiveness of agriculture here find their highest expression. Small peasant farming is the general rule. Sheep have dwindled to small proportions, both absolutely and relatively to other agricultural enterprises. In France since 1870 there has been a decline in numbers of sheep of 57 per cent; in Denmark of 88 per cent since 1881; in Belgium one of 49 per cent between 1880 and 1910; in Holland one of 24 per cent between 1877 and 1921. In Germany there has been a decrease of 84 per cent since 1870, only a very small proportion of which is accounted for by change in territory; from 1870 to 1910 there has been a decline of over 50 per cent. In Hungary there was a decline of 48 per cent between 1870 and 1910. Thus a decline of from 50 to 90 per cent in the last sixty years is characteristic of the countries of north-western Europe. The decline was no doubt accelerated by the War, both directly and indirectly, but it was in progress before the War and has continued since.

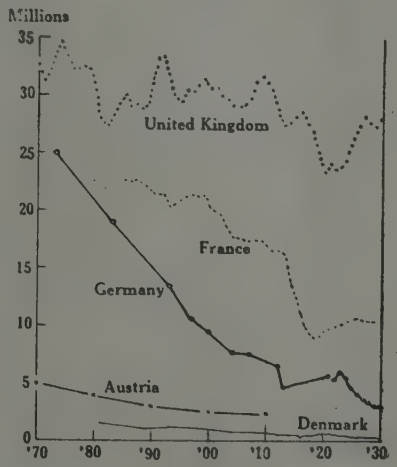

FIG. 3
Numbers of sheep in some European countries, 1870–1930

THE BRITISH ISLES.

As already stated, the British Isles form an exception to the general rule in that a high density of sheep population accompanies a high degree of industrialization, density of human population, and land value. It has also been pointed out, however, that the greater numbers are found in the countries where there are large areas of hill and moorland of low value. Sheep are least numerous in the arable countries

of the south and east, an exception being Kent, where large flocks are grazed on the famous Romney marshes.

In the British Isles the use of small farm flocks on arable, mixed and grass farms has attained a special development. On arable farms, especially on light soils, they form an integral part of the systems which have been built up on the rotations introduced by the improvers of the eighteenth century. On grass farms they are supplementary to cattle in the use of grazing land. Their place in the various systems forms an interesting subject which cannot here be discussed. It may be said, however, that their persistence in contrast with the case in neighbouring countries is to be correlated with the relative absence of the small peasant type of farming, a consideration which gives point to their comparative unimportance in Southern Ireland.

Nevertheless, the factors which have been observed in operation in other parts of the world are in evidence here too. The historical development from the middle ages shows a progression from wool production to mutton. In the last sixty years there has been a decline in total numbers. In England and Wales there has been a shift from the arable and farming areas where agriculture is more intensive to the poorer, hillier and more remote areas of the west and north. In Scotland, however, the movement has been reversed, a decline having taken place in the highland counties and an increase in the eastern arable counties. For this apparent contradiction various explanations have been advanced, such as the unsuitability of the more rugged areas to any but the hardier sheep, which have met a declining market, and the extension of deer forests. The subject is an intricate one, and space does not allow of its development in this article.

Conclusion.

The main observation to be drawn from the foregoing facts is that farm systems can be arranged in a sort of ascending or descending series with land values as a corresponding series showing a definite correlation and, further, that sheep farming varies in importance and character in different parts of the series. It appears first in the "extensive" end of the series, where land values are lowest, and here reaches its highest importance, both absolutely and relatively to other agricultural enterprises. It here takes the form of a specialized industry with wool production as the main object. As we pass towards the "intensive" end of the series sheep farming declines in importance both absolutely and relatively, and it also changes its character. It enters into supplementary and complementary relations with other enterprises in mixed farming systems. The importance of wool declines and that of meat increases, mutton gives place to lamb. Finally, at the intensive extreme, sheep all but disappear.

Though here and there exceptions are found, it is evident that there is a general rule in operation. It is not suggested that the general rule indicates the ultimate cause. To some extent the rule merely provides a preliminary analysis of the elements of the problem. Ultimate causes lie deeper. They determination involves a historical analysis of the use and value of sheep husbandry in a wide variety of farming systems, of the marketing influences that have affected mutton and wool, of changes in the amount and quality of produce per sheep which have been considerable, and, finally, of the factors influencing the course of commercial sheep farming and other agricultural pursuits, both at the extensive and the intensive margins.

For References see page 288

Essential Oils

IV.—Oils from Exotic Plants: Geranium Oil

By V. A. BECKLEY, *M.C., M.A., A.I.C., Senior Agricultural Chemist, Department of Agriculture, Kenya Colony.*

The oil known as geranium oil is not derived from a member of the genus *Geranium* at all, but from a species of *Pelargonium*, the horticultural "geranium". There is one oil, Zdravetz, produced from a true *Geranium*. Sometimes, too, palma rosa oil, derived from the grass *Cymbopogon Martini* var. *motia*, is known as Turkish geranium oil.

Geranium oil, of a sort, has been produced commercially for some years past in Kenya. In the initial stages, the present main producers experimented with several varieties, finally choosing one that gave a comparatively high yield—0.2 to 0.25 per cent. The oil was marketed under the name of "Mawah", by which name it is known to-day, and is regarded by the trade as not a true geranium oil. Thus Mawah oil and geranium oil must be regarded as two different oils.

Mawah oil has always sold at a certain discount below geranium oil. It therefore appeared desirable to search for a better variety. Immediately it became apparent that countries producing geranium oil were very loath to permit any planting material to leave. Eventually, strains of typical oil-producing varieties were obtained from Kew, South Africa, and one or two private sources. In addition, a large number of other species and varieties were obtained and planted at the Scott Agricultural Laboratories for study.

Meanwhile, one of the large producers, Mr. W. J. Dawson, of Njoro, multiplied a French strain which had been tried earlier. This strain is a comparatively low yielder, but gives a fine oil. In a few years he was able to establish a true geranium oil on the market, an achievement which will be of great value to future development.

There is a very great divergence of opinion in textbooks regarding the botanical name of the oil-producing geranium. *P. roseum, P. graveolens, P. radula, P. capitatum, P. odoratissimum,* and *P. fragrans,* have all been stated to be the origin of the oil. One wonders if some of these names are not fancy horticultural names, with no real botanical meaning. Neither the true *P. odoratissimum* nor *P. fragrans* is suitable for cultivation for oil production. The former consists of a mass of radical leaves with a few long, trailing, flowering branches, while the odour is most unattractive. *P. fragrans* is a small, bushy shrub of a pleasant odour, unlike geranium oil. The name *P. roseum* is certainly a garden name for *P. graveolens* and *P. radula* types.

Several varieties of *P. capitatum,* some derived from seed of wild plants, have been under trial, but while some carry a pleasant oil none has the true geranium oil. Since one variety was obtained from the Seychelles as being the true Bourbon strain, one is tempted to the conclusion that the statement, that *P. capitatum* is the origin of some of the true geranium oils, is incorrect. Some of the strains under trial here are promising, and are being studied further.

This leaves us with *P. graveolens* and *P. radula.* Certain of our varieties have been identified at Kew as *P. graveolens,* others as *P. radula.* None of these strains comes true as seedlings. In the *P. grav-*

eolens group, there is every stage, from plants with an almost entire leaf with highly sinuate edges, to those with highly dissected leaves having little lamina left. The Pelargoniums readily cross, and soon after their introduction into Europe hybrids were being produced. Probably here we are concerned with a hybrid plant, in some strains of which the floral characteristics of *graveolens* predominate and in others those of *radula*. Some strains are very strong-growing, have large leaves, and a marked purple coloration at the nodes, sometimes visible externally, but always visible on cutting across the stem. Every strain of this type gives a fair yield of Mawah-like oil.

Besides these species, several others have been under observation, some of which are of interest and may be valuable as sources of oil. *P. crispum* is a strong-growing, tall species, having small leaves with a clean, verbena-like odour. This species does fairly well at Nairobi, but grows more freely at altitudes over 8,000 feet. It is certainly well worth while experimenting with this species. *P. angulosum* grows very strongly at Nairobi. In a year the growth is over five feet high. When the leaves are rubbed in the hands, the odour is rather unpleasant; but soon a strong rosy note develops that is most persistent. Direct distillation gives no oil. In the last distillation made, the material was chopped up and allowed to stand overnight, in case the scent was developed by fermentation. Again no oil separated, but the water had a strong rosy odour. Extraction with ether gave a small quantity of oil, in which were identified alcohols and either aldehydes or ketones. It is possible that some use may be made of this plant, and planting is being extended.

As far as *P. capitatum* is concerned, neither the "Attar of Rose" variety nor that purporting to be the true Bourbon strain is of any value. Both are semi-prostrate, and give a minute yield of oil, less than 0.01 per cent. Two seedling strains of South African origin are promising. Both give erect, strong-growing, leafy plants. Selection work on seedlings from these strains might give a valuable variety.

The first strain of the *radula* group to be obtained at the Scott Agricultural Laboratories was one from the National Botanical Gardens, Kirstenbosch, C.P., which has been called "S.A." It was originally obtained from Grasse. During the writer's absence on leave, four geranium plants, all *P. radula* group, arrived from Kew. These were planted as a single variety, and for convenience were termed "*Q*". It soon became evident that there were at least two varieties; further study and selection led to the separation of two more varieties, giving the following strains: "*Q*", "*Var.* 1", "*Var.* 2", "*Var.* 3". Two varieties were obtained locally, one from Mr. W. J. Dawson, which was classed as "*Var.* 4", the other from Mr. Gilbert Walker, "*Var.* 5". Two other varieties were imported. One was sent to the writer by Professor B. de St. J. van der Riet, of Stellenbosch University, a seedling strain derived from "S.A.", and thought to be of great promise. The other was supplied by the Tanganyika Department of Agriculture. Three other varieties have recently been obtained, but are of no value as oil producers.

Of the nine strains of the *radula* group, "*Var.* 1" will be discussed first. This is a strong-growing, leafy, erect plant, shy of flowering and showing the peculiar purple coloration at the nodes mentioned earlier. It yields from 0.09 to 0.15 per cent of an oil closely approaching Mawah in character.

"*Var. S.A.*" is a fairly strong-growing, leafy variety, with a tendency to become procumbent. It flowers readily, but so far no seedling strains have appeared here. It appears to be rather susceptible to root-rot, but the disease has not spread here. This strain has done well at high altitudes, and produced a good oil. At the Scott Agricultural Laboratories the yield of oil has been of the order of 0.1 to 0.15 per cent, the ester content of which has been high. All the reports upon the oil have been good, and it is stated the oil would command a ready market.

"*Var. Q*" is very similar in growth habits to "*Var. S.A.*" It has not suffered so much from root-rot as the latter. Very good reports have been received of its behaviour in regions of heavy rainfall, where it has done better than other varieties. The yield of oil has always been slightly lower than that from "*Var. S.A.*", but the oil is practically identical in chemical constitution and odour.

"*Var. 2*" is very similar to "*S.A.*" and "*Q*", but tends to be more procumbent. Since there was nothing strikingly different in the yield or the character of the oil, this variety was not multiplied beyond the experimental patch, and has now been dropped.

"*Var. 3*".—In appearance this variety is practically identical with "*Q*" and "*S.A.*", but tends to be more erect and leafy. It stands up to drought conditions better than any of the others, and appears to be less susceptible to root-rot. The oil yield fluctuates considerably, having varied from 0.1 per cent to 0.25 per cent. Apparently the high yields have usually been obtained after a protracted drought. On this account this strain has been tried in areas subject to drought, where it has done well. The quality of the oil, like that of "*Q*" and "*S.A.*", is good and will command a ready sale. In fact, these three oils so closely resemble each other that they may be mixed.

Seedling Strain of "S.A."—This is a very erect variety with much-divided leaves. The yield of oil is satisfactory, but although the analytical results are promising, the odour of the oil is most unattractive. The London report on the oil was laconic: "No good."

Tanganyika Strain.—This variety closely resembles the last in appearance. The yield of oil is low and the quality poor.

Neither of these two last varieties is worth cultivating, not even for ornamental purposes.

Propagation.

It is evident that the only way of propagating the good strains of oil-producing geraniums is by means of cuttings. In many textbooks it is stated that the best cuttings are those with "heels". The experience at the Scott Agricultural Laboratories is that cleanly severed cuttings are satisfactory; a sharp knife must be used, not secateurs. Cuttings with the terminal bud and a few leaves are the best; it is possible to strike cuttings without a terminal bud provided a few leaves are left.

The writer prefers cuttings about 12 in. long, from nearly mature wood, with short internodes. This gives a stocky, erect plant from the beginning. More whippy wood may be used, as also may simple tip cuttings, but there is a tendency for the first growth to be prostrate.

In some places it is possible to plant the cuttings directly into the fields and obtain a high percentage of strikes. At the Scott Agricultural Laboratories, even planting into nursery beds under shade

gave very few strikes, since the cuttings were always infected with a fungus. In one case, out of 1,100 cuttings, only 5 plants were obtained. Cuttings were treated with permanganate, corrosive sublimate, and copper sulphate without success; watering the soil with Cheshunt mixture was also useless. Finally, we were driven to building a sand bed, in which nearly 100 per cent strike. Elsewhere, the writer has seen cuttings in nursery beds strike perfectly. Everyone must experiment to ascertain the most suitable method for his own area.

Cultivation.

The experimental plots at the Scott Agricultural Laboratories are planted 30 in. by 30 in., and usually a good growth completely shades the ground, smothering weeds. Such planting will not be possible under all conditions. In some districts it will be necessary to cultivate with implements to keep down weed-growth and to break the soil; a wide spacing between the rows may be needed, while the plants may be closer in the row.

The writer has advised that cutting for distillation should be done when the leaves turn yellowish. It is not always possible to do so. A long rainy season gives a very heavy growth which, if not cut, becomes long, whippy and woody, with little leafage. Naturally, the yield of oil from such material will be low. The writer's own practice now is to cut while the branches are still leafy; again the yield from sappy material will be lower than from ripe material, if still leafy, but much higher than from whippy, woody stuff. Authorities state that such oil is inferior, but this depreciation in quality has not been detected in oil produced in Kenya. The writer is of the opinion now that sunshine is of more importance, and that cutting should only be done in bright sunshine.

Although geranium does give a very full cover to the soil, and a good deal of litter accumulates, there are times after cutting when the soil will be bare and exposed to erosion. Growers are urgently advised to adopt some anti-erosion measures, preferably broad-base ridge terraces.

Distillation, etc.

The principles of distillation have already been discussed in the first article of this series. There are one or two points that need mention. The oil is contained only in the leaves; the stems contain none. Theoretically, only the leaves should be distilled; but the cost of stripping the leaves will be greater than that of the extra steam needed to heat the stems. Therefore all the material as cut is distilled. It may be advisable, in order to obtain even packing, to pass the material through a cutter.

Since the oil has a value of Sh. 15 to Sh. 20 per pound, it is worth while ascertaining the exact point to which it is economical to continue distillation.

Around the distillery there will be a vast accumulation of waste. It has often been said this cannot be converted into compost; the writer has done so within a month, and even the stout stems were broken down. It must be remembered that the material as it comes from the still is sterile and must be inoculated from a compost or manure heap before proper decomposition will occur. Once a series of heaps has been started, and regular cross-inoculation is practised, a plentiful supply of good compost will be obtained for return to the fields. Geranium takes off a good deal of plant food, which must be returned if the productivity of the fields is to be maintained.

It sometimes happens, if the tinning has been worn away from the swan-neck of the still or from the condenser, that the oil will be coloured green. In bad cases the oil carries a heavy black scum. Both the green colour and the scum are due to copper. The green colour may be faint at first, but becomes more pronounced after a few days. When it is accepted on the market that a certain oil has a yellow colour, a consignment tinged green will be regarded with suspicion. It is, however, a simple matter to remove the colour when it has fully developed. Shaking the oil, in a separating funnel, with a half per cent solution of tartaric acid in water removes the colour without affecting the oil.

Yield.

The yield of oil per acre has been difficult to ascertain. Until recently, experiments at the Scott Agricultural Laboratories aimed at learning if time of cutting affected the oil appreciably. The produce from a quarter-acre plot of "Q" variety was recently distilled as a whole. This plot had received no special treatment, but was run on commercial lines; that is, blanks were not filled up, no special cultivations were given, nor any manures applied. The yield of oil from a four to five months' growth was at the rate of just over 16 lb. per acre. This figure cannot be taken as a standard, since the yield will depend on the amount and type of growth. Close leafy growth will carry more oil than lanky growth that has lost much of its leaf. However, it does appear that a yield of 20 to 35 lb. of oil per acre per annum may be expected.

Pests and Diseases.

In the earlier part of the experimental work it was the practice to collect all insects found during the cutting of the various geraniums. With the exception of a few leaf-eating caterpillars, no insects have caused any damage. One species, however, *P. pinnatum*, has been infested by, and suffered severely from, cottony cushion scale.

At the Scott Agricultural Laboratories, occasional plants have died from a root-rot, which has been identified as being caused by *Rhizoctonia solani*. The damage has been very slight, and has seldom spread to neighbouring plants. No other disease has been observed. A peculiar condition has developed at Njoro, where the growth after cutting is very bunchy and small-leaved. The cause of this is obscure, but it appears that no pathogen is concerned.

Disease in cuttings is common, and has already been discussed.

As geranium oil is comparatively high priced, the demand is much less than for the somewhat similar and cheaper palma rosa oil. If geranium oil could be offered at Sh. 5 to Sh. 6 per pound, the demand would increase enormously. Since, however, the cost of production lies between Sh. 9 and Sh. 14 per pound, a fairly high price must be maintained.

As a result of the limited demand, the market is very sensitive to over-production, and development must proceed slowly. It does appear, however, that it would be possible for the market to-day to absorb the produce from about 2,000 acres of geranium of the *radula* group. The Mawah market is still more restricted, and it is to be doubted if it could absorb more than the present production.

The constants of the oils from the main varieties of geranium grown at the Scott Agricultural Laboratories are as follows:—

Mawah.

Specific gravity, 15°C.	0.839
Rotation	−20.65°
Refractive index ...	1.4693 to 1.4711
Acid value	0.45 to 6.4
Ester value	8.7 to 27.1
Esters % (as Geranyl tiglate)	3.67 to 11.4
Total alcohols ...	82.7%

"Q."

Specific gravity, 15.5°C.	0.894 to 0.9014
Rotation	−9.28° to −12.8°
Refractive index ...	1.4693 to 1.4705
Acid value	1.12 to 6.3
Ester value	63.28 to 74.86
Esters % (as Geranyl tiglate)	26.67 to 31.55
Free alcohol	38.0% to 54.8%
Total alcohol	58.5% to 72.2%

"S.A."

Specific gravity, 15.5°C.	0.9001 to 0.906
Rotation	−9.17° to −13.19°
Refractive index ...	1.4695 to 1.4721
Acid value	2.06 to 7.3
Ester value	71.8 to 88.1
Esters % (as Geranyl tiglate)	30.3 to 37.13
Free alcohol	48.9%
Total alcohols ...	70.4%

Var. 2.

Specific gravity, 15.5°C.	0.9005 to 0.902
Rotation	−11.73° to −14.17°
Refractive index ...	1.4691 to 1.4711
Acid value	5.42
Ester value	73.5
Esters % (as Geranyl tiglate)	30.98
Free alcohol	47.3%
Total alcohol	67.5%

Var. 3.

Specific gravity, 15.5°C.	0.8982 to 0.904
Rotation	−10.58° to −14.1°
Refractive index ...	1.4695 to 1.4710
Acid value	5.6 to 7.5
Ester value	74.0 to 76.5
Esters % (as Geranyl tiglate)	31.2 to 32.25
Free alcohol	38.2 to 52.2
Total alcohol	58.5 to 73.2

(*Continued from page* 286)

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The Control of White Stem Borer of Coffee

By R. M. DAVIES, *B.Sc., B.Sc. (Agric.), Senior Agricultural Officer, Department of Agriculture, Tanganyika Territory.*

The present seems to be a suitable time to review our experience of the control of this coffee pest in the Northern Province. I therefore propose to restate the conclusions of the late Mr. Ritchie, Entomologist to the Department, published in his annual reports; also to make known the experience of many planters and agricultural officers in carrying out control measures over a period of years. The assistance that has been readily given by planters in co-operating to deal with this pest has been invaluable, and is greatly appreciated.

HISTORY.

The White Coffee Stem Borer, *Anthores leuconotus* Pasc., is indigenous to the locality, and is able to cause widespread damage to coffee, particularly at the lower elevations, on Kilimanjaro and Meru below 4,500 feet. This is often referred to as the "borer belt".

Ritchie found that there were at least five wild rubiaceous trees or shrubs on which the borer naturally existed. He failed to find any predators or parasites upon the insect in its various stages. Before the introduction of coffee the numbers of borers throughout the area must have been fairly constant. Figures are given later of the average population of borer larvæ extracted from large numbers of host trees which have been destroyed. It is interesting that this is very much lower than counts taken from neglected coffee.

The growing of coffee as a pure crop in large compact blocks created an artificial supply of a host plant, and thus favoured the increase of the borer. The War period and immediately after were vital years, because very little was being done to control any pest. When proper control started again it was obvious that a great deal of leeway had to be made up. Numbers of mature beetles had bred uninterrupted. There was the additional handicap that, because of purely financial considerations, a large number of the coffee trees infested in the bad years were allowed to remain when it would actually have been more profitable to have taken drastic action, uprooted the trees and replanted. A badly infested coffee tree may have as many as 18 borer grubs in it at one time. When established in the tree in such numbers not more than a third of them can be extracted by the wiring method.

In support of what has been said above regarding the position when control was unsatisfactory, the following table of figures is given. It is a typical example of the state of affairs when control began in earnest: —

Period of operations.	*No. of adult borers caught.*	*No. of borer larvæ extracted.*
During part of 1st year, from September to December ...	5,014	41,397
During whole of 2nd year ...	5,482	12,592
During whole of 3rd year ...	513	5,076
During part of 4th year, from Jan. to Aug. ...	28	390

The figures are from a census of a block of 31,000 coffee trees.

DAMAGE.

There are no means of accurately assessing the damage which borer causes to the industry. This is because it is not

similar to that caused by insects belonging to many other categories in which the destruction is related to the amount of food the insect eats. Nevertheless, the damage that borer does to the tree is probably far greater than is generally realized. It is not as spectacular as the work of pests such as thrips, locusts or army worms. The market wants coffee of high quality. Only well-tended and vigorous trees can produce the plump, full-bodied coffee which the market is crying out for. Trees weakened by the attack of borer grubs can only be expected to produce an inferior coffee, of which the world at the moment has far too much. Vigorous trees producing quality coffee are wanted and this means, given good season, attention, hard work, and control of pests and diseases.

Control Methods.

Ritchie constantly emphasized that success in borer control depends upon perseverance and thoroughness. He made the pest the subject of major investigation over a considerable period in the Northern Province, at the same time taking the matter up with entomologists throughout Africa. The investigation continued until early in 1935. There are several main facts connected with his work on the pest, having a direct bearing on control, which should be restated. The control measures advocated are seen to be simple and obvious: —

1. Single-stem coffee trees are advisable for simplicity of inspection and treatment, because crotches of multiple-stem trees provide favoured points for oviposition. Also, in the treatment of coffee trees, anything tending to the production of stubs or nobbly outgrowths must be avoided, since it is at such points that grubs will be missed or difficult to extract.

2. The eggs are laid behind the bark at or about ground level, there being no evidence of oviposition below that level. Being inserted to a slight depth, the egg is fairly safe from outside influences.

3. It is the larval stage of the insect that causes the damage to the coffee tree. For the first four months the young grub works superficially. It can be detected by the slight raising of the bark which it disturbs as it travels underneath it. If the detectable grub is missed during this period it enters the tree, tunnelling within, and does not come to the outside of the tree, and is consequently safe from outside influences. The insect pupates within the tree, and this resting stage, during which transformation takes place, is therefore also protected.

4. Some of the grubs from eggs laid at ground level travel in the superficial root tissues below ground. The removal by hand of such grubs necessitates the exposure of the root system close up to the central taproot. Protectives for the stem at ground level have been the subject of experiment, without success so far.

In carrying out the control methods it is important that the period of flight of the adult borers in each district should be known because hand grubbing should commence at a date so related to this flight period that resulting grubs will have reached a size detectable by the borer inspection gang. For example, with flight in May, grub work is from September onwards; too early a beginning will mean missing many small undetectable grubs.

The borer gang should be provided with a piece of rough hessian to rub the bark of the trees vigorously. This reveals the grubs working superficially, and they can be destroyed. For any grub which has entered the tree a foot of No. 24 gauge iron wire should be used to follow up its track and extract it. A small file to keep the wire point well sharpened is necessary.

The use of chemicals like paradichlorbenzine for insertion in borer grub holes is not recommended, except in instances where extraction is impossible save by sacrificing the entire tree or considerable sections of it.

Coffee in a borer area when stumped back to near ground level must even then, though showing a clean saw-cut, be thoroughly examined below ground. A hundred per cent clearance in old infected trees is unobtainable, and the material is best uprooted.

Cost of Control.

Writing in 1934, Ritchie says on the subject that: "Where plantations have given thorough attention to the method of control of white borer set out in the Report of 1932, the number of borer grubs have, in comparison with pre-existing conditions, been very considerably reduced; indeed, in places, to the vanishing point." As regards plantation coffee, the cost of control measures has been ascertained from a number of experienced planters, together with information as to what can be accomplished to reduce the pest to a satisfactory level. Mr. W. H. Baldwin, of Mkoloen Estate, Moshi District, has provided the following table and account, which he has very kindly given me permission to publish:—

BORER CONTROL

Mkoloen Estate, Moshi. 80 Acres Altitude 3,700 ft.

Period	No. of grubs extracted	Period	No. of beetles caught	Total cost in Sh.	Cost per acre in Sh.
March 1932 to March 1933	No record	March to July 1932	No record	591/82	7/39
Sept. 1933 to March 1934	6,203	March to July 1933	860	513/23	6/41
Sept. 1934 to Dec. 1934..	2,850	March to June 1934	331	450/22	5/62
Sept. 1935 to Nov. 1935	1,055	March to July 1935	49	368/40	4/60
—	—	March to July 1936	4	—	—

Mr. Baldwin writes as follows:—

"In reply to your inquiry about the control of White Borer (*Anthores leuconotus*) in coffee on this estate, I am pleased to give you the following information, covering a period from March, 1932, up to the present time. I have enclosed a summary of borer larvæ extracted from the trees, cost of larvæ extraction, and the number of adult beetles captured.

The area of coffee covered by the figures is about 80 acres, having an average of 800-850 trees per acre.

I have no record of the number of larvæ extracted prior to September, 1933, and for this reason I have given the cost of working of one such year only, March, 1932, to March, 1933. Prior to the campaign started in September, 1933, I had no definite plan of control. Work was carried on throughout the year, without any regard to the time of maximum emergence of the adult beetle.

Although the costing of such a year's work was higher (wages were slightly more) than since a definite plan was adopted, the infestation was obviously a serious major problem. Considerable damage to the trees was always apparent. In fact, borer seemed to be getting the upper hand.

In September, 1933, I began a thorough campaign on the lines advised by the Entomologist. the late Mr. A. H. Ritchie. This campaign finished in March, 1934, fifteen acres having been done a second time. Subsequent campaigns have started in September and have been finished in November or December. Maximum emergence of adult beetles takes place in this area during April and May. If the larvæ are extracted three or four months later the damage done is negligible.

The eradication of wild host trees on my own land and the partial eradication on adjoining native lands has doubtless aided the control.

You will notice that the 1935 costs are the lowest. Nevertheless, each tree was thoroughly examined. On this estate larvæ are mostly found below ground level, and in consequence each tree is examined to below the first lateral roots, often to a depth of ten or twelve inches.

The adult beetles have been collected voluntarily, a reward of 5 cents always being given for each beetle.

Having concluded the yearly campaign about November, I do no further work in borer control (apart from the collection of beetles) until the following August or September. This has been my practice since the conclusion of the 1933 campaign.

On the 24th of this month I started this year's campaign in a block of 13,000 trees. In 1933 this block gave 2,490 borer; last year 164 borer, and this year 101 borer only. The work in this block is now finished.

An examination of my figures shows a decrease from 6,203 larvæ in the 1933 campaign to 1,055 larvæ in last year's campaign. There is every indication this year's total will show a further reduction. I therefore consider that borer control on the lines laid down by Mr. A. H. Ritchie is completely satisfactory; provided that systematic yearly control is maintained, it would seem that I should have no anxiety about the future."

Borer in Native Coffee.

On the native coffee plots, borer campaigns are carried out each year. On Kilimanjaro the work is generally done communally. Growers from each sub-district gather together and work through the plots one by one. A record is kept of the numbers of plots in which any grubs are found, and the total number of grubs obtained. In the earlier campaigns trees which were badly infected were either uprooted or stumped. Although natives are good at extracting borer in the superficial workings, they are inclined to pass over grubs which have entered the tree.

Records from two districts in which formerly the borer infestation had proved to be most severe show that in only 7 per cent of the total number of plots were any grubs found at all during the last campaign. In the affected plots the grub population averages between 3 and 4 per hundred trees. In the earliest campaign in 1930 only superficial borings were worked on, but in the subsequent campaign approximately 18,000 badly affected trees were uprooted or stumped. In other districts in only 3 per cent of the total number of plots were any grubs found at all, though in these plots the grubs averaged between 3 and 4 per hundred trees.

Experience in the native coffee indicates that by strict supervision of control work the borer population has been brought to a very satisfactory and safe figure. There is every reason to believe that further improvement can be effected.

Host Trees.

Mention has been made that there are wild trees or shrubs, hosts of the borer, scattered throughout the coffee area. Of suspect hosts studied the following were found to contain borer: —

Scientific name (with native names in brackets).

Oxyanthus speciosus D.C. (Mrali, Elimanubi, Kahawa ya porini, etc.)
Randia sp. (Mbuchi, Mroyo, Mdengedenge.)
Vangueria sp. (Mroo, Mtoo, Kiwero, etc.)
Pavetta Oliveriana Hiern. (Kifufu.)
Rytigynia Schumanii Robyns. (Mroo Mdogo.)

These have been gazetted under the Plant Pest and Disease Regulations, and it is incumbent upon the owner, occupier or person having the charge or management of any land on which these occur to remove and destroy them.

Generally speaking, the *Randia* and *Vangueria* species are the two commonest. Both are medium-sized trees, up to 30 ft. high and 12 in. in diameter. *Vangueria* is the favourite of the borer, and, incidentally, the fruit of this tree is much relished and eaten by natives and their children. *Oxyanthus speciosus* is rather similar to coffee in appearance. It is not common in

the lower areas. *Rytigynia* and *Pavetta* are bushes, the former common above 4,000 feet and the latter found in all areas.

Within the boundaries of blocks or plots of coffee, eradication is reasonably complete. It is realized, however, that the task of eradication of these in the vicinity of coffee is a formidable one which will take time to effect. In the tribal lands of Kilimanjaro and Meru over two million host trees have been taken out. Counts of borer larvæ in a considerable number of these trees were made and the population in them averaged 6 per cent. Variations according to locality ranged from less than 1 per cent to 15 per cent. Again there was found to be variation from tree to tree over small areas, many trees being untouched, whereas a particular tree would have numbers of borer larvæ in it.

As regards density of host trees, accurate figures are not available, but it is estimated that between twenty and thirty per acre represents a maximum figure. The expenditure in labour is between ten to thirty trees or bushes per man-day, according to circumstances. One of the bigger trees of *Vangueria* may take four to five men a whole day to deal with. Most of the species regenerate readily from roots, and consequently very thorough work is necessary if it is to give permanent results. The aim is ultimately to get the whole area cleaned of these host trees. The figures given above of counts of larvæ in host trees show that although no artificial control measures have been practised against them they are not as heavily infested as coffee can be when neglected. In fact, if the coffee throughout the area carried no greater a population than the host trees there would be very little to trouble about.

Legislation.

Apart from the legislation to clear the host trees, there is legislation to control the pest. Inspections are made regularly, and when the position regarding borer is unsatisfactory orders are issued to the owner stating what is required to be done and a time given in which the order is to be carried out. Failure to comply with the requirements of the order makes the person served with it liable to prosecution. There is also provision for a summary prosecution without notice or an order. In general the carrying out of these measures works effectively and fairly smoothly. Such legislation would be of very little use unless it was well backed up by an informed public opinion, which fortunately it is.

We know from past experience that borer increase constitutes a real danger, so that all producers of coffee interested in the welfare of their industry should accord their sympathetic co-operation in the enforcement of any measures to control such a pest. For his own sake, every grower must keep his plantation clean and healthy. If he does not, then steps have to be taken to protect his neighbours.

In conclusion, it should be said that, although the control methods are simple, the points which have to be stressed regarding them are that they require very careful supervision, and that at least 50 per cent of the borer workings, once they have entered the trees, are below ground level. Such simple measures are sometimes criticized on the grounds that they are not up to date, but it is significant that in the United States of America, where labour is anything but cheap, the hand method is still practised against the peach and apple borer.

Arabica Coffee and the Plant Breeder

By COLIN MAHER, *M.A., Dip. Agric. (Cantab.), A.I.C.T.A., Agricultural Officer, Department of Agriculture, Kenya Colony.*

INTRODUCTION.

It is well known that most tropical crops have not had the attention devoted to them in the matter of selection and breeding that has been given towards raising fruits, such as apples, peaches and other crops, to the stage of excellence attained in the temperate zones. Many of the chief crops of the tropics are plantation crops—coffee, cacao, rubber, sisal, coco-nuts and others—which often take several years to come into bearing and still longer before individual tree or plant records may be procured that are sufficiently reliable to serve as the basis of breeding operations.

It is evident that no great progress could be made in the improvement of these tropical crops by plant breeding methods till the requisite scientific staff was available in the various countries concerned, and until continuity of long-term work could be guaranteed. In general, it has only been during the last thirty or forty years that these facilities have been obtained; such facilities have been provided to a marked degree perhaps only during the last fifteen or twenty years, and there is still room for improvement in this respect. It may be added that the average plant breeder in the tropics has a career of not longer than twenty-five years. As far as the British Empire is concerned, the system of transferring officers of Agricultural Departments to other territories often may tend to interrupt still further the work of improvement which is being attempted on any particular plantation crop. In temperate countries, however, a considerable amount of crop improvement and breeding is undertaken commercially by the larger seedsmen and horticulturists, while individual breeders' work may be extended over considerably more than twenty-five years. It is evident, therefore, that successful work on these tropical crops, which may only mature two or three successive generations during one breeder's active career, is completely dependent on a long-range plan for improvement and breeding of the crops and on continuity in policy being preserved at established experiment stations by the succession of scientific officers employed.

At the same time, no country can be expected to pay out money year after year solely for the maintenance of research work that may possibly benefit the succeeding generation (and even this result —owing to the nature of the task—may be open to doubt). An official breeding programme which had as its only aim the obtaining, in thirty years' time or more, of pure lines of crop plants which would breed true to type, from seed, for all the characteristics desirable in the crop, would find little favour amongst practical planters, many of whom may be conscious of advancing years. While such a Utopian aim must not be entirely neglected, it is fortunate that many of the tropical plantation industries can call to their aid the arts of the horticulturist.

Thus a considerable amount of attention is being devoted to-day all over the tropics to the vegetative propagation of such crops as cacao and coffee; by this means good hybrids or other desirable types of plants of the crops, which would yield a very uneven and perhaps useless seedling progeny, can be multiplied for immediate use on commercial plantations.

While fresh interest has been aroused of late years in the possibilities of vegetative reproduction of coffee, this is no new thing, since the multiplication of plants by means of layering or by rooted suckers was employed in Martinique over two hundred years ago, while grafting of coffee has been carried out since the eighteenth century.

The Need for Improvement in *Coffea arabica.*

Chevalier, in his very able, fairly recent work, *Les Caféiers du Globe,* has dealt with the question of coffee improvement so admirably that little opportunity is left for any other writer to add anything fresh to the subject. The present writer therefore must make his grateful acknowledgments to the inspiration of Dr. Chevalier's work, while confessing his inability to contribute further in any degree to the full discussion given by Dr. Chevalier on the objects to be gained and the means to be used in the improvement of coffee.

Very little has been done towards the improvement of *Coffea arabica* by means of selection and breeding. The varieties under cultivation are usually the end-products of adaptation and the more or less unconscious selection that has taken place in various coffee-growing countries of the world. It is doubtful if the types of coffees that are at present cultivated differ materially from the ancestors of these coffees, which were derived from the forests of South-West Abyssinia. The Abyssinian variety, Harar, is probably only three or four generations removed from the wild crops of the mountains in the south-west.

It is plain that a fruitful field is open for the application of modern botanical knowledge and of present-day plant breeding methods to the betterment of "Arabian" coffee.

The foremost husbandmen in this field must be the workers at well-found experiment stations. They must render to the planter the improved seed, the plants or the selected clonal material for grafting which are to make his labours more profitable.

As in the practice of fruit-growing, the most unpromising stocks, which perhaps give poor and irregular crops of poor berries, may prove to be most successful in their power of adaptation to the ecological environment and their resistance to the attacks of disease. The desirable qualities in commercial coffee, which will be described later on, are partly dependent on the properties of the soil and partly on the skill and care devoted to preparation; but these characteristics may be expected to be largely due to the intrinsic properties of the variety. Experiment has yet to prove this relation of, for example, that obscure thing "quality" in coffee; but it would be strange indeed if varieties of coffee were not found to differ in chemical composition and flavour in the same way as many varieties of fruits differ one from the other.

High quality and these subtle differences in flavour of varieties of fruits have been developed and isolated by careful selection and skilled culture over a great number of years. It is not to be expected that similar gratifying results will be obtained with *Coffea arabica,* so recently growing wild in its native forests, unless a similar devoted attention is given to the crop; and only by careful selection and breeding can such faults as defective beans and poor cropping—and, perhaps, even poor liquoring quality—be eliminated. However, if the necessary attention is paid to the crop, both in cultivation and selection, there is no reason why the species should not rapidly improve in economic value.

The Requirements of a Good Variety of Coffee.

1.—*Yield and Vigour.*

The coffee must give a good average yield over a ten-year period. While a high average yield may be attained by means of one or two very heavy crops during such a period of several years, it is generally more satisfactory if the trees bear regularly and fairly evenly year by year.

In East Africa it has been found that biennial bearing may often be accounted for by poverty of the soil or by the use of wrong methods of cultivation, so that root pruning is effected. The provision of shade or the maintenance of a higher condition of fertility in the soil will often prevent the occurrence of this condition, with which dieback is often associated. Chevalier believes, however, that biennial bearing is, at least in part, a varietal characteristic, and states that the "National" coffee of Brazil is particularly prone to this failing. He points out also that the character of fertility and of setting a good proportion of the flowers is not only dependent on the soil and on the nature of the season, but it also depends on individual characters.

The coffee must have the faculty of developing rapidly, when conditions are favourable, a good bush, in which the branches are well spaced and which are able to bear a heavy crop without physical or physiological difficulty.

Chevalier remarks that in the average plantation which has been raised from seed, numerous variations may be seen in the heterozygous progeny; thus pyramidal or rounded bushes, erect branches and drooping branches may be seen. During the last few years it has been observed in East Africa that pyramidal growth may not only be due to cold but to poor soil fertility, bad planting, unsuitable cultivation, or other causes. Nevertheless, the tendency to show a particular habit of growth is definitely hereditary. At present the only means by which a plantation of uniform trees can be obtained is by means of grafting, and this has not yet become a commercial practice in East Africa.

2.—*Adaptation.*

The coffee must be chosen for each district that is best able to compete with the adverse conditions that are liable to occur in that district. These conditions include such climatic factors as excessive cold at night and rapid changes of temperature, extreme heat, prolonged dry seasons, very high humidity at certain seasons; biological factors include attacks by various insect pests or fungal diseases.

By selection, varieties could eventually be isolated that are resistant to these adverse factors and which might be said to be adapted to the district in which these adverse conditions are operative. It must be borne in mind, however, that there are limits, both practical and economic, to the degree of adaptation that may be procured by means of selection. No one attempts to select coco-nut palms for cultivation on a glacier, and attempts to obtain coffee varieties suitable for all parts of East Africa must equally have their practicable bounds. In some instances, the area in which certain peculiar circumstances occur may be so small that the labour and expense involved in procuring suitable coffee varieties for the district could never be economically justified.

The coffee must also have the power of making vigorous growth in the kind of soil in which it is required to grow. It must be free from signs of chlorosis when growing in such a soil, and must be able to absorb its mineral requirements—again within reasonable limits—from such mineral reserves as are present in this soil. Some varieties will need a rich, deep soil,

while others will do well on a light, stony soil. Obviously, the degree of adaptation will to a large extent depend on the nature of the root systems of the various varieties; the suitability is not yet known of the different varieties for the several types of soil upon which coffee is grown in East Africa.

It is a great asset, of course, if a variety is not exacting in its requirements as to soil, and Chevalier observes that the "National" *arabica* coffee of Brazil is very accommodating in this respect.

It will probably be found that certain types of coffee can only be grown successfully under shade, while other types apparently are uninjured by considerable exposure to strong light. In general, the question of "shade or no shade" will be decided by the climate in the various districts, by the number of cloudy days, and so on. Coffee is usually grown without shade in Brazil, but the industry has grown up there by gradually advancing into the forest lands where the soil has not yet deteriorated. Far more difficulty is experienced, anywhere in the world, in growing coffee without shade on impoverished soil than if suitable trees, or artificial shade, are employed.

3.—*Quality of the Bean.*

This subject leads us into deep and uncharted waters. The vagaries of coffee-tasters are notorious, and a chemical basis has yet to be found for that phantasmagoric virtue "quality" in coffee. Commercial tradition demands, however, that the beans shall be of good average size and of marketable shape and colour. The beans should be as heavy as possible; light beans are usually abnormal or immature. There must be a sufficient content of caffeine, and the roasted beans or liquor must have a good aroma. The beans of the variety must give a homogeneous sample.

The extent to which these various characters are hereditary is still a matter of doubt. It is thought that the greater part of these characteristics could be maintained by means of grafting, though it is probable that the stock can also influence, to some degree, the chemical composition of the bean and the aroma of the final product.

Selection of *Coffea arabica.*

"Selection" is practised when seed is chosen with care in order to improve cultivated plants or to perpetuate highly desirable races which have originated by mutation or hybridization.

"Mass selection" is the act of cultivating successive generations of a plant, choosing seed from the best plants in each generation.

This method of plant improvement gives good results, and the fruit trees of temperate climates have owed much to this kind of work. However, if the crop that is being worked with is very mixed in genetical constitution and many characters are being considered, this method is very slow, even with annual crops. The desired types often appear in only very small proportions, especially in the earlier phases of the work, and inferior "throw-backs" are apt to be numerous.

Sometimes the patient plant breeder may be rewarded by the spontaneous appearance of a desirable type, perhaps due to a gene mutation. Many well-known apple trees—X's "Seedling" or Y's "Pippin"—have arisen from such chance discoveries, and the selector of coffee must ever be on the watch for such a lucky happening, nor must he remit his labour in experimenting with a wide range of "types" or "varieties".

These varieties with the sought-after characteristics may be found in any plantation derived from seed. If the seed from

a selected tree is sown and plants are re-selected in successive generations, it should be possible eventually to secure homozygous races; that is, pure races which can reproduce themselves faithfully by seed. In the meantime, cross fertilization should be avoided by planting the seed from selected trees in each generation in large blocks, isolated as far as possible from other coffee.

It will be evident that the individual planter could not carry on this breeding work, which needs to be pursued at experimental stations with sufficiently strong resources of finances and land, and a stable scientific personnel. The planter can give invaluable assistance to the experiment station by observing and marking the desirable trees from which seed may be obtained. On his part he can multiply by means of grafts the superior trees chosen on his own or neighbouring plantations; thereby he can eventually replace his own miscellaneous coffee by plantations of uniform trees that are known to be well adapted to the soil and climate of the region in which he lives.

The planter who wishes to buy coffee seed or young plants often buys on the strength of a varietal name, or of the reputation of some plantation that may be situated in a far-away district with entirely dissimilar climatic and soil conditions. There is rarely or never any guarantee that the seed has been picked from high-yielding, disease-resistant trees or that the parent trees were not cross-pollinated by inferior trees. In some cases, seed sold from an estate on which two varieties are growing side by side does not even give rise to plants with the external characteristics of the variety from which it is purported to be derived. The natives picking the "seed" may have been paid on a piecework basis, and the easiest coffee to pick, regardless of variety, was the coffee most remunerative to the picker. The purchaser of seed of some named variety from this estate may be surprised afterwards at the number of types which appear in the plantation constituted of trees grown from this seed.

The careful planter will select his own seed or, failing this, will buy it from a near neighbour of good repute as a coffee-grower. Seed should be taken from trees which are old enough to have proved their yielding ability and powers of disease resistance; the parent trees must be vigorous and fertile, and well adapted to the soil and climate of the district; the beans must be of desirable type, and uniform.

Chevalier recommends that every plantation should have its own little experimental plantation, isolated from the other coffee, in which selected types can be transplanted and kept for the production of seed; each variety or type should be set apart in order to avoid crossing. The obtaining of mother trees for the production of seed or scions is work of the first importance, and there should be no hesitation about discarding inferior types. Apart from other considerations, it will be necessary, also, to avoid making the experimental plantations too extensive.

Experimental Coffee Plantations and Seed Farms.

The experimental coffee station must not only devote its attention to the multiplication of a few selected strains for the production of seed for issue; it must include amongst its activities the collation and maintenance of a living coffee "museum". It has been an accepted principle amongst plant breeders for many years that one of the first activities of the breeder who is engaged on the improvement of a crop should be the establishment of a complete collection of the known varieties of the crop. The activities

of the agricultural scientists of the U.S.S.R. during the last few years have placed an entirely new interpretation on this principle. The Russians make collections which run into thousands—in some cases, scores of thousands—of varieties and species of each major crop plant in which they are interested; not only cultivated forms but wild types are collected. There is another point in which the Soviet agronomists might well be emulated by agricultural departments in the Colonial Empire. While reliance is often placed, with varying success, on the interest and knowledge of foreign correspondents for the forwarding of materials for these living plant collections in imperial countries, the Russians send expeditions of skilled scientists who collect their material in person; by this means alone could their vast collections have been made.

Thus all known species, varieties and types of coffee, cultivated and uncultivated, should be gathered together on the experiment stations of East Africa. The wild coffee in the forests on the mountains of South-West Abyssinia should yield a rich multiplicity of types which might suit a corresponding variation in conditions in the coffee-growing areas of East Africa.

Desirable strains may be multiplied, on the stations, by grafting, and each strain should be cultivated on a plot containing at least twenty trees. When any plants are seen in a commercial plantation which have some at least of the desirable characteristics that have been described earlier on, seed or graft scions should be taken in order to study the strain in the experimental plantation. It is essential that the parent tree should be marked at the same time for future observation.

It may perhaps be mentioned here with advantage that metal labels should be used for marking the trees by farmers who are selecting individual desirable trees. These labels may be hung on the trees by means of wire. The labels may be of brass, which can be scratched with a wire nail, or of zinc or tin, which may be painted upon by means of a pointed piece of wood. Further, the position of the tree should be counted (as the number x tree in row y) for reference, and perhaps a tall pole set beside the tree to facilitate finding the tree for making the observations.

It has been said that wild coffee trees should be included in the "museum"; not only wild coffee species but other plants of the family *Rubiaceae* may be included with advantage. It may be possible to effect crosses with these plants and with cultivated coffee, or they may be of utility as stocks.

Hybridization.

Hybridization is a valuable means which may be employed in the improvement of coffee. Since the progeny of a hybrid are not likely to be "true to type", the hybrid tree of desirable type must be multiplied by asexual means. It may be multiplied, that is to say, by its use as clonal material for grafts, it may be multiplied by striking cuttings, or by establishing rooted suckers.

Most hybrids of importance hitherto, such as most of those which have played a valuable part in the development of the coffee industry in the Dutch East Indies, have originated spontaneously. There is no reason, however, why success should not attend attempts to produce valuable hybrids by artificial cross-pollination. At the same time self-fertilization should be continued in some lines in the hope of isolating valuable recessive characters.

All members of the *Eucoffea* section can be crossed among themselves. It is evident therefore that an infinite number

of forms, differing both physiologically and morphologically, could be obtained by systematic breeding.

While the hybrid material may be used in grafts, it is also desirable to make attempts to obtain a pure line or lines of coffee from the hybrid. In order to carry out this project it is necessary to plant a large number of the progeny seeds and to allow the plants to grow on until they have borne a few crops. The best plants are then re-selected, the rest are rejected, and the process is repeated, generation by generation, till a few plants remain or even one plant of great excellence.

Generally it is necessary to make several crosses in such breeding work, and it will be seen that the process is a very lengthy one.

It will probably be found necessary, in order to ensure complete uniformity, to raise the grafts of any hybrid or selected plant on similar stocks; failing seedling stocks which are sufficiently even, it may be necessary to raise the stocks themselves by cuttings. This refinement is likely to be necessary at least for coffee that is required for experimental purposes, if it is not essential for commercial plantations.

As Chevalier points out, the scientific use of hybridization affords great possibilities for the improvement of coffee. It should be possible to obtain for each major coffee district, a variety that is to a large extent resistant to the chief pests and diseases and which would not suffer through climatic irregularity. Such a variety would be prolific and ripen uniformly, while being suited to the soil of the area and giving coffee of high quality. It would be still more advantageous if such a coffee could reproduce itself by seed.

It must be acknowledged that such an accomplishment represents the *aim* of a plant breeder. The necessary tedium of the process has been repeatedly emphasized. The workers at an experiment station, while hitching their wagon to a star, must have a more immediately available form of terrestial traction: that is to say, the provision of selected seed and clones for immediate use by planters must not be neglected, even though it may be clearly recognized that this material is far from representing the hoped-for ultimate achievement.

(*Note.*—This article has been intentionally written in the abstract. No mention has been made of the work on vegetative propagation and selection of coffee that has been done or is in progress in East Africa. Some of this work has been described in previous numbers of this Journal, and no doubt subsequent articles will be published referring to further work.—C.M.)

A Revised List of Plant Diseases in Tanganyika Territory

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This list contains the records of fungi and plant diseases of economic interest made in Tanganyika Territory between the years 1927 and 1936. With a few additions and amendments, it combines lists already published in the Kew Bulletin.(1)

The majority of the identifications have been made or confirmed by the staff of the Imperial Mycological Institute, Kew. Certain diseases, including Bark Disease of Coffee, Brown Streak of Cassava, and Yellows of Tea, have been described and recorded by Dr. H. H. Storey, Plant Pathologist of the East African Agricultural Research Station, Amani. Several of the records on wheat have been made by Mr. J. McDonald, Senior Plant Pathologist in Kenya Colony, and the majority of those of tobacco have been made or confirmed by Dr. J. C. F. Hopkins, Senior Plant Pathologist in Southern Rhodesia.

The form of the present list closely follows that recently made by the Senior Plant Pathologist in Kenya Colony, which has proved to be convenient for reference.(2) It will be noted that the hosts of Armillaria are listed together at the end.

It must immediately strike the reader with a knowledge of the major diseases of crops in the world that East Africa is singularly free from the more dangerous parasitic fungi and bacteria. This can be accounted for, to a large extent, by the comparative youth of the country and by the enactment of legislation, the object of which is to prevent the entry of diseased plant material. There are no measures, however, which can be entirely effective, and this opportunity is taken to request the further co-operation of planters and others in the Territory in bringing any suspected new disease to the attention of the Department of Agriculture. Without the co-operation of planters and agricultural officers in the past in submitting material for identification this list would not be so comprehensive as it is.

REFERENCES.

(1) *Kew Bulletin of Miscellaneous Information*, No. 1 of 1932, pages 1-12, and No. 3 of 1936, pages 234-240.

(2) *The East African Agricultural Journal*, I, 6, May, 1936, pages 463-468.

LIST OF DISEASES.

ACACIA, Indigenous (*A. campylacantha* Hochst. ex A. Rich.).
In roots, *Ustulina zonata* Lév.

ALMOND (*Prunus Amygdalus* Stokes).
Crown gall (*Bacterium tumefaciens* E. F. Sm. and Towns.).

ALOE, Indigenous (*Aloe* sp.).
Rust, *Uromyces Aloës* (Cooke) P. Magn.

APPLE (*Pyrus Malus* L.).
Crown gall (*Bacterium tumefaciens* E. F. Sm. and Towns.).

ASPARAGUS (*A. officinalis* L.).
Rust, *Puccinia Asparagi* DC.

AVOCADO (*Persea Americana* Mill.).
Algal leaf spot, *Cephaleuros mycoidea* Karst.

BAMBARRA GROUNDNUT (*Voandzeia subterranea* Thou.).
Mildew, *Erisiphe Polygoni* DC.
On roots and fruit, *Sclerotium Rolfsii* Sacc.

BANANA (*Musa sapientum* L.).
On fruit, *Gloeosporium Musarum* Cooke and Mass.

BARLEY (*Hordeum vulgare* L.).
Net blotch, *Helminthosporium teres* Sacc.
Covered smut, *Ustilago Hordei* (Pers.) Lagerh.
Brown rust, *Puccinia anomala* Rostrup.

BEANS—
DOLICHOS LABLAB L.
Yeast spot of seed, *Nematospora Coryli* Pegl.
LIMA BEAN (*Phaseolus lunatus* L.).
Leaf blotch, *Ascochyta Phaseolorum* Sacc.
Yeast spot of seed, *Nematospora Coryli* Pegl.
RUNNER BEAN (*Ph. vulgaris* L.).
Rust, *Uromyces appendiculatus* (Pers.) Link.
On leaves, *Isariopsis griseola* Sacc.
Anthracnose of pods, *Colletotrichum lindemuthianum* (Sacc. and Magn.). Bri. and Cav.
Root disease, *Rhizoctonia bataticola* (Taub.) Butl. (C. strain).
SWORD BEAN (*Canavalia ensiformis* DC.).
Leaf spot, *Cercospora* sp. (apparently not *C. Canavaliae* Syd.).
On collar and pods, *Sclerotium Rolfsii* Sacc.
TEPARY BEAN (*Ph. acutifolius* A. Gray).
Yeast spot of seed, *N. Coryli* Pegl.

BOUGAINVILLAEA (*B. spectabilis* Willd.).
On twigs, *Phomopsis* sp.

BULRUSH MILLET—
PENNISETUM CILIARE (L.) Link.
"Asali" disease, *Sphacelia* sp. and *Cerebella* sp.
P. SPICATUM Schult. (*P. typhoideum* Stokes).
On leaves, *Phyllachora Penniseti* (?) Sydow.
Rust, *Puccinia Penniseti* Zimmerm.
Downy mildew and green-ear disease, *Sclerospora graminicola* (Sacc.) Schroet.
"Asali" disease, *Sphacelia* sp. and *Cerebella Sorghi-vulgaris* Subram.
Smut, *Tolyposporium Penicillariae* Bref.

CABBAGE (*Brassica oleracea* L.).
Leaf spot, *Alternaria circinans* (B. and C.) Bolle.

CACAO (*Theobroma Cacao* L.).
On dead branches and pods, *Nectria Jungneri* P. Henn. and *Botryodiplodia Theobromae* Pat.
In pods, *Phytophthora* sp.
In roots, *Usulina zonata* Lév.
On dead stump, two *Rosellinia* sp. and *Kretzschmaria cetrarioides* (Welw. and Curr.) Sacc.

CAPE GOOSEBERRY (*Physalis peruviana* L.).
White smut, *Entyloma Physalidis* (Kalchbr. and Cooke) Wint.

CARNATION (*Dianthus Caryophyllus* L.).
Rust, *Uromyces caryophyllinus* (Schrank) Wint.
Leaf spots, *Septoria Dianthi* Desm., and *Alternaria Dianthi* S. and H.

CASSAVA (*Manihot utilissima* Pohl.).
Leaf spot, *Cercospora Henningsii* Allesch.
Mosaic and Brown Streak, virus diseases.
On leaves, *Mycosphaerella Manihotis* Ghesq. and Henrard non Syd. (prob.).
On stems, *Botryodiplodia Manihotis* Syd.

CASTOR (*Ricinus communis* L.).
On leaves, *Cercosporina ricinella* (Sacc. and Berl.) Speg.
Powdery mildew, *Ovulariopsis* sp.
Rust, *Melampsorella Ricini* (Biv. Bern.) de Toni.

CELERY (*Apium graveolens* L.).
Leaf spot, *Cercospora Apii* Fresen.

CHILLI PEPPER (*Capsicum annuum* L.).
On fruit, *Alternaria tenuis* Nees, *Gloeosporium piperatum* Ell. and Ev., and *Vermicularia Capsici* Syd.
On collar, *Sclerotium Rolfsii* Sacc.

CITRUS—
LEMON (*Citrus Limonum* Risso).
On twigs and branches, *Haplosporella* (*Sphaeropsis* sp.).
On bark over form of canker, *Physalospora fusca* N. E. Stevens.
LIME (*C. aurantifolia* (Christm.) Swingle).
Algal leaf spot, *Cephaleuros mycoidea* Karst.
ORANGE (*C. Aurantium* L.).
On leaves, *Alternaria tenuis* Nees, *Colletotrichum gloeosporioides* (Penz.) Sacc.
Scab, *Sporotrichum Citri* Butler.
Ring blotch (physiological).
In fruit, *Nematospora Coryli* Pegl., *Diplodia gossypina* Cooke, *Penicillium digitatum* Sacc., *Phytophthora palmivora* Butler, and *Polyopeus* sp.
At collar, *Cytospora* sp.

COCO-NUT (*Cocos nucifera* L.).
Leaf spot, *Pestalozzia palmarum* Cooke.
On leaf sheaths, *Diplodia epicocos* Cooke.
"Gummosis," a physiological disease of nuts.

COFFEE—
COFFEA ARABICA L.
Brown blight of leaves and cherries and on twigs, *Colletotrichum coffeanum* Noack.

Brown eye-spot of leaves and cherries, *Cercospora coffeicola* B. and C.
Rust or Leaf Disease, *Hemileia vastatrix* B. and Br.
On leaves, *Leptosphaeria coffeicola* Maubl.
On twigs, *Leptosphaeria* sp. and *Phomopsis* sp.
"Witches' Broom" effects, associated with infestation by the Coffee Bug, *Antestia lineaticollis* Stal., and also with cold and high altitudes.
"Cherry-fall" (physiological).
Coffee Bean Disease, *Nematospora Coryli* Pegl., and *N. Gossypii* Ashby and Nowell, spread by the Coffee Bug, *A. lineaticollis* Stal.
Coffee Bark Disease, *Fusarium lateritium* Nees var. *longum* Wr., and *F. Solani* var. *eumartii* (Carp.) Wr.; at collar, base of new shoots, and on leaves and cherries.
Collar dry rot, associated with infestation by Mealy Bug, *Pseudococcus brevipes* Ckll. (syn. *P. bromeliae* Bouché).
Warty disease, *Botrytis cineria* Pers. (A disease closely associated with cold and wet conditions at higher elevations. A sterile gemmiferous fungus causes spotting and falling of leaves and cherries, and of leaves of tea and other crops.)
Root disease, *Rhizoctonia bataticola* (Taub.) Butl. (*Macrophomina Phaseoli* (Maubl.) Ashby).

C. LIBERICA Bull. ex Hiern.
Algal leaf spot, *Cephaleuros mycoidea* Karst.

COTTON (*Gossypium hirsutum* L.).
Angular leaf spot, Black Arm and Boll Rot, *Bacterium malvacearum* E. F. S.
Areolate mildew, *Ramularia areola* Atk.
Rust, *Kuehneola Gossypii* Arthur.
On leaves, *Alternaria tenuis* Nees, *Mycosphaerella gossypina* (Atk.) Earle, and *Phyllosticta Malkoffii* Bubak.
On stems, *Diplodina* sp.
Internal boll disease, *Nematospora Gossypii* A. and N.
In bolls, *Aspergillus niger* van Tiegh, *Diplodia gossypina* Cooke, *Gibberella moniliformis* Winel., *Monilia sitophila* group.
On roots, *Rhizoctonia Crocorum* (Pers.) D.C.

DAHLIA (*Dahlia* sp.).
White smut, *Entyloma Dahliae* Syd.

DATE PALM (*Phoenix dactylifera* L.).
False smut, *Graphiola phoenicis* (Moug.) Poit.

DRACAENA, Indigenous (*Dracaena* sp.).
On leaves, *Dothiorella* sp.

EGG PLANT (*Solanum Melongena* L.).
Rust, *Aecidium* sp.
On leaves, *Alternaria* sp. (not *A. Solani*).

FIG (*Ficus Carica* L.).
Rust, *Kuehneola Fici* Butl.

FLAMBOYANTE (*Poinciana regia* Boj.).
In roots, *Ustulina zonata* Lév.

GRAM—
BLACK (*Phaseolus radiatus* L.).
Mildew, *Erysiphe Polygoni* DC.
Yeast spot of seed, *Nematospora Coryli* Pegl.
GREEN (*Ph. mungo* L.).
Leaf spot, *Cercospora* sp.

GRAPE VINE (*Vitis vinifera* L.).
Downy mildew, *Plasmopara viticola* (Berk. and Curt.) Berl. and de Toni.
Powdery mildew, *Uncinula necator* (Schw.) Burr.

GRASSES—
GUINEA GRASS (*Panicum maximum* Jacq.).
On leaves, *Coniosporium inquinans* Dur. and Mont.
LEMON GRASS (*Cybopogon citratus* Stapf).
Rust, *Puccinia Cymbopogonis* Mass.

GROUNDNUT (*Arachis hypogaea* L.).
Leaf spot, *Cercospora personata* (B. and C.) Ellis.
Rosette disease (virus).

KAPOK (*Ceiba pentandra* Gaertn.).
Leaf spot, *Ramularia Eriodendri* Racib.
In roots, *Ustulina zonata* Lév.

LENTIL (*Lens esculenta* Moench).
Mildew, ? *Erysiphe Polygoni* DC.

LILY, GOLDEN (*Hemerocallis aurantiaca* Baker).
On leaves, *Vermicularia liliacearum* Westend.

LOQUAT (*Eriobotrya japonica* Lindl.).
On leaves, *Ascochyta Eriobotryae* Vogl.

MAIZE (*Zea Mays* L.).
Downy mildew, *Sclerospora* sp.
Leaf blight, *Helminthosporium turcicum* Pass.
Rust, *Puccinia Maydis* Béreng.
Streak, a virus disease.
Head smut, *Sorosporium Reilianum* (Kühn.) McAlp.

Ear rots, and on old stalks, *Gibberella Saubinetii* (Mont.) Sacc., *Fusarium moniliforme* Sheld. (*G. moniliformis* (Sheld.) Winel.), *Diplodia Frumenti* Ell and Ev., *D. macrospora* Earle, *D. Zeae* Lév.

On old stems, *Clasterosporium Lindavianum* Reichert, *Leptosphaeria eustoma* (Fr.) Sacc. forma *Zeae* Berl., *L. orthogramma* Sacc., *Nigrospora sphaerica* (Sacc.) Mason, *Papularia sphaerosperma* (Pers.) von Höhn. (group), *P. vinosa* (Berk. and Curt.) Mason, *Phaeocytostroma ambigua* (Mont.) Petr.

MULBERRY (*Morus* sp.)—

M. ALBA L.

On stem, *Sphaeropsis Mori* Berl.
Rust, *Kuehneola Fici* Butl.

M. INDICA L.

Mildew, *Ovulariopsis moricola* Del.
On leaves, *Septogloeum Mori* (Lév.) Br. and Cav.
On leaves and stems, *Bacterium Mori* B. and M.
On stems, *Eutypa ludibunda* Sacc., *Sphaeropsis heterospora* Passer.

NASTURTIUM (*Tropaeolum majus* L.).
Mildew, *Oidiopsis taurica* (Lév.) Salm.

OKRA (*Hibiscus esculentus* L.).
On leaves, ? *Colletotrichum Hibisci* Pollacci, *Libertella affinis* D. Sacc.
On old fruits, *Myrothecium roridum* Tode.

OLEANDER (*Nerium Oleander* L.).
Leaf spot, *Cercospora neriella* Sacc.
Bacterial spot on leaves and stems, *Pseudomonas Savastanoi* E. F. S., var. *Nerii* C. O. Smith.

OXALIS, Indigenous (*Oxalis* sp.).
Rust, *Aecidium* sp., apparently not *P. Maydis* Béreng.

PAPAW (*Carica Papaya* L.).
Mildew, *Ovulariopsis Papayae* van der Bijl.
On fruit, *Colletotrichum gloeosporioides* (Penz.) Sacc.
Disease of leaves very like virus.

PEAS—

COWPEA (*Vigna unguiculata* Walp.).
Leaf spot, *Cercospora cruenta* Sacc.
Yeast spot of seed, *Nematospora Coryli* Pegl.

FIELD PEA (*Pisum sativum* L.).
Mildew, *Erysiphe Polygoni* DC.

PIGEON PEA (*Cajanus Cajan* Millsp.).
Leaf spot, *Cercospora Cajan* P. Henn.
Mildew, *Oidiopsis taurica* (Lév.) Salm.
On stems, *Lisea* sp.
Yeast spot of seed, *Nematospora Coryli* Pegl.
In roots, *Rhizoctonia* sp.

PEACH (*Prunus Persica* Stokes).
Leaf curl, *Taphrina deformans* (Berk.) Tul.
Rust, *Puccinia Pruni-spinosae* Pers.
Crown gall, *Bacterium tumefaciens* E. F. Sm. and Towns.

PEAR (*Pyrus communis* L.).
Crown gall, *Bacterium tumefaciens* E. F. Sm. and Towns.

PINEAPPLE (*Ananas sativus* Schult. f.).
Base rot, *Ceratostomella paradoxa* Dade.

PLUM (*Prunus domestica* L.).
Rust, *Puccinia Pruni-spinosae* Pers.
Crown gall, *B. tumefaciens* E. F. Sm. and Towns.

POTATO (*Solanum tuberosum* L.).
Early blight, *Alternaria Solani* (E. and M.) J. and G.
"Spraing" in tubers (virus).
Powdery scab, *Spongospora subterranea* Wallr.

PUMPKIN (*Cucurbita Pepo* L.).
Leaf spot, *Cercospora Cucurbitae* Ell. and Ev.

QUININE (*Cinchona* sp.).
On twigs, *Phomopsis* sp.

RICE (*Oryza sativa* L.).
Blast, *Piricularia Oryzae* Cav.
Brown spot, *Helminthosporium Oryzae* van Breda.
False smut, *Ustilaginoidea virens* (Cke.) Tak.
On heads, *Phyllosticta glumarum* Sacc.

ROSE (*Rosa* sp.).
Mildew, *Sphaerotheca Humuli* (DC.) Burr.
On twigs, *Gloeosporium* sp., *Pestalozzia versicolor* Speg.
Crown gall, *Bacterium tumefaciens* E. F. Sm. and Towns.

RYE (*Secale cereale* L.).
Brown rust, *Puccinia secalina* Grove.

RUBBER (*Manihot Glaziovii* Müll.).
Mosaic or leaf-curl (virus).

SANSEVIERIA (*Sansevieria* sp.).
On leaves, *Leptosphaeria* sp.

SESAME (*Sesamum orientale* L.).
- Leaf spots, *Cercospora Sesami* Zimm., *Helminthosporium gigasporum* B. and Br., sub-sp. *javanicum* Penz. and Sacc. (provisionally).
- Mildew, *Oidium erysiphoides* Fr.
- Leaf-curl (probably virus).
- Bacterial leaf-spots and stem lesions.

SISAL (*Agave sisalana* Perrine ex Engelm.).
- On leaves, *Botryodiplodia Theobromae* Pat., *Colletotrichum Agaves* Cav., *Microdiplodia Agaves* (Niessl.) Tassi, Cucurbitaria Agaves Syd. and Butl.
- In stumps, *Aspergillus niger* van Tiegh., *Podospora* sp., ? *Hypocopra austro-americana* (Speg.) Sacc., var. *Agavis americanae* Speg.
- Various physiological leaf diseases, Banding disease, Sun scorch, Scald, etc.

SORGHUM or GUINEA CORN (*Sorghum vulgare* Pers.).
- Downy mildew, *Sclerospora Sorghi* (Kulk.) Westeon and Uppal.
- Rust, *Puccinia purpurea* Cooke (with *Darluca filum* (Biv.) Cast.).
- Leaf spot of young plants, *Ascochyta sorghina* Sacc.
- Grain smut, *Sphacelotheca Sorghi* (Link.) Clint.
- Head smut, *Sorosporium Reilianum* (Kuehn) McAlp.
- Long smut, *Tolyposporium Ehrenbergii* (Kuehn) Pat.
- Loose smut, *Sphacelotheca cruenta* (Kuehn) Potter.
- "Asali" disease, *Sphacelia Sorghi* McRae, and *Cerebella Sorghi-vulgaris* Subram.
- On heads, *Acrothecium lunatum* Wakker, *Alternaria tenuis* Nees (group), *Choanephora Cucurbitarum* (Berk. and Rav.) Thaxter, *Fusarium* sp., *Gibberella moniliformis* Winel., *Phoma insidiosa* Tassi, *Rhinotrichum cucumerinum* Berk. and Curt., *Trichothecium roseum* (Pers.) Link.

STRAWBERRY (*Fragaria vesca* L.).
- Leaf spot, *Mycosphaerella Fragariae* (Tul.) Oudem.

SUGAR CANE (*Saccharum officinarum* L.).
- Leaf spots, *Cercospora longipes* Butl., *Leptosphaeria Sacchari* van Breda, *Pleocyta Sacchari* (Mass.) Petr. and Syd.
- Mosaic (virus).

SUNFLOWER (*Helianthus annuus* L.).
- Mildew, *Erysiphe Cichoracearum* DC.

TEA (*Thea sinensis* L.).
- Leaf spot, *Colletotrichum Camelliae* Massee.
- Algal spot, *Cephaleuros mycoidea* Karst.
- Scabbed leaves (physiological).
- On twigs, *Stilbella Theae* Bernard.
- Yellows disease (sulphur deficiency).
- Crown gall, *Bacterium tumefaciens* E. F. Sm. and Towns.
- Root disease, ? *Fomes lamaoensis* Murr. (fructifications not seen).

TEPHROSIA VOGELLI Hook. f.
- Yeast spot of seed, *Nematospora Coryli* Pegl.

TOBACCO (*Nicotiana Tabacum* L.).
- Frog-eye spot, *Cercospora Nicotianae* Ell. and Ev.
- Blackfire (physiological).
- Leaf-curl (virus).
- Leaf spot, *Alternaria tabacina* (Ell. and Ev.) Hori.
- Mildew, *Erysiphae cichoracearum* DC.
- Mosaic (virus).
- ? Hollow stalk, *Bacillus carotovorus* L. R. Jones.
- Wildfire, *Bacterium Tabacum* Wolf and Foster.

TOMATO (*Solanum Lycopersicum* L.).
- Mosaic (virus).
- Leaf spot, *Septoria Lycopersici* Speg.

VANGUERIA ACUTILOBA Robyns (Indigenous).
- *Hemileia Woodii* Kalchbr. and Cooke.

VERBENA (*Verbena* sp.).
- Mildew, *Erysiphe Cichoracearum* DC.

WASHINGTONIA FILIFERA H. Wendl.
- On leaves, *Diplodia epicocos* Cooke, *Pestalozzia versicolor* Speg., *Phoma palmicola* Winter.

WHEAT (*Triticum vulgare* Vill.).
- Brown rust, *Puccinia triticina* Erikss.
- Stem rust, *P. graminis* Pers.
- Yellow rust, *P. glumarum* (Schm.) Erikss. and Henn.
- On leaves, *Epicoccum purpurascens* Ehrh.
- Glume blotch, *Septoria nodorum* Berk.
- Black chaff, *Bacterium translucens* var. *undulosum* Smith, Jones and Reddy.
- Loose smut, *Ustilago Tritici* (Pers.) Jens.

ZINNIA (*Zinnia* sp.).
- Mildew, *Oidium* sp.

Armillaria.

Living host-plants of *Armillaria* in Tanganyika Territory are recorded below. Fructifications have been seen on only one plantation, on dead stumps of forest trees among affected tea bushes; they were identified as *A. mellea* (Vahl.) Quél.:—

Acacia podalyriaefolia.
A. dealbata Link (Silver Wattle).
A. decurrens Willd. (Black Wattle).
Acacia sp. (Indigenous).
Acrocarpus fraxinifolius Wight & Arn.
Albizzia moluccana Miq.
Cajanus Cajan Millsp. (Pigeon Pea).
Calodendron sp.
Cedrela odorata L.
C. Toona Roxb. ex Rottl.
Chlorophora excelsa Benth. and Hook. f. ("Mvule").
Citrus Aurantium L. (Orange).
C. Limonum Risso (Lemon).
Coffea arabica L.
Crotalaria sp.
Cupressus lusitanica Carr.
Cyphomandra betacea Sendt. (Tree Tomato).
Eriobotrya japonica Lindl. (Loquat).
Eucalyptus citriodora Hook.
E. globulus Labill.
Erythrina lithosperma Blume.
Grevillea robusta A. Cunn.
Hibiscus Rosa-sinensis L.
Jacaranda sp.
Manihot utilissima Pohl (Cassava).
Musa sapientum L. (Banana).
Rosa sp.
Saccharum officinarum L. (Sugar Cane).
Sesbania sp.
Thea sinensis L.
Trema guineensis Priem.
Widdringtonia Whytei Rendle (Mlanje Cedar).

Entomogenous Fungi.

Entomophthora Apidis Hoffm.—Parasitic on *Aphis luguminosae* on *Arachis hypogaea.*

Tetracium coccicolum von Höhn. (the conidial stage of *Podonectria coccicola* (Ell. and Ev.) Petch.).—Parasitic on scale insects on leaves and twigs of *Citrus* sp.

Sphaerostilbe aurantiicola (B. and Br.) Petch.—Parasitic on scale insects on leaves and twigs of *Citrus* sp. The conidial stage (*Microcera aurantiicola* Petch.) was present, but scanty.

Construction of a Sod Bank

By MAJOR T. A. BUDGEON, *Nanyuki, Kenya Colony.*

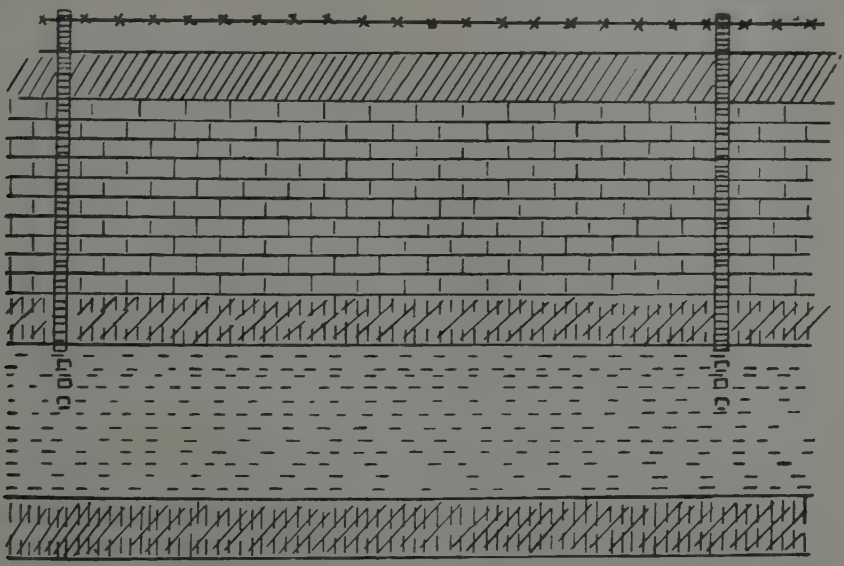
The following instructions should be of interest to farmers in Kikuyu grass areas. The type of sod bank described provides a thoroughly effective permanent fence: —

Place a line of pegs 6 to 8 yards apart along line of proposed bank.

Make holes for posts, say 3 ft. deep, where the pegs are. The holes should be dug at a slight incline so that the posts slope inwards towards the crest of the bank.

similar line of *temporary* posts should then be erected opposite to the above, at a distance of 5 ft. or 6 ft., according to the thickness of the base of the bank, inclined slightly towards the crest (5 ft. is a sufficient width at the base for a 5 ft. bank, and 3 ft. 6 in. at the crest). To keep the proper angle or incline of the bank, these posts should be tied with a piece of string so that they are 3 ft. 6 in. apart at a height of 5 ft. from the ground.

Nails should then be driven into these



Sketch Plan of a Sod Bank—Kongaita Type

The posts should then be put in. If permanent posts are required, 9 ft. cedar posts should be used, to which a strand of barbed wire can be fixed when bank is completed, above the line of bank. These should be well rammed in. Otherwise, temporary posts can be used, say 8 ft. long, and removed and used again as each section of the bank is completed. A

posts at a distance of 6 in. from the ground. A length of thin wire or strong string should then be fixed to these nails, and stretched taut on the inside and outside posts for the alignment of the first line of sods.

A single, or preferably double, furrow mould-board plough should then begin to plough up the sods about 6 in. deep, be-

ginning 6 in. to 8 in. from the line of posts and turning them outward away from the posts. These should be cut into lengths of about 2 ft. by the labourers (with a *panga*). One end should be cut square. These sods should then be laid close together, with the square ends close to the wire (but not actually touching the wire, as they would cause it to bulge). When the two lines of sods are laid in line with the inner and outer wires, then the space in between should be filled in with broken sods and loose earth, and stamped down, leaving the centre of the bank slightly concave. The plough meanwhile returns, turning the next row of sods inwards, which are removed by the labourers and laid along the wires.

When the first line of sods is completed and the centre of the bank filled in, the nails are removed and driven in 6 in. higher, and the wire stretched taut again for the next row of sods. These should be laid similarly close together and close to the wires, but should be inclined downwards slightly towards the centre of the bank to preserve the right angle, otherwise they will be apt to bulge or slip outwards with the pressure from above. The centre of the bank is filled in again and stamped down.

This process is repeated until the bank reaches the required height, say 5 ft., i.e. 10 rows of sods.

As the work proceeds and the sods have been removed for a space of 6 ft. to 8 ft. from the bank (i.e. the line of posts), the plough digs up the earth along this strip on the *outside* of the bank to provide soil for the labourers for filling up the centre of the bank, and at the same time making a ditch, 6 ft. to 8 ft. wide, which increases the height of the bank. The ditch when completed should be about 18 in. deep. The area beyond the ditch is ploughed up as far as is necessary for the extra sods required; probably about 6 yards from the line of posts on the inside as well as the outside of the bank.

As the plough will not be able to plough up the turf right up to the posts, the labourers should finish off the ditch on the outside with mattocks, cutting a straight face to the bottom of the ditch from close to the edge of the bank, leaving no step.

When the bank is completed, some 2 in. of loose earth should be thrown on top and the crest should then be planted with strips of Kikuyu grass. After a few months this will become a solid mass of Kikuyu grass, which will grow down into the bank and bind it. It might be advisable also to put slips of Kikuyu grass on the top of each layer of sods as they are built up, projecting slightly beyond the edges. Where the bank is being built of sods turfed with Kikuyu grass this, of course, would not be necessary.

The best time for building these banks is during the rains. Where the soil is suitable (i.e. not sandy loam) rain helps to bind them quickly.

It is quite easy to arrange task work. It has been found that raw Merus can do a section of 6 yards per man in three days (i.e. 2 yards per day) on a bank 5 ft. high (plus ditch, 18 in. = 6 ft. 6 in. total height). The cost under normal conditions should be under £20 per mile, including one strand of wire.

The Unsuitability of Certain Virgin Soils to the Growth of Grain Crops.—II.

In continuation of the discussion initiated by Mr. N. V. Rounce (*East African Agricultural Journal*, Vol. II, No. 2, p. 145), we now publish the following note by Mr. H. R. Hosking (Assistant Botanist, Uganda Department of Agriculture) upon his experience with cotton on so-called virgin land in the light soil areas of the East Province of Uganda:—

"For some years past we have known that it is not good practice to clear land from bush and to plant cotton immediately. If this is done, the cotton shows a distinct yellowing of the leaves, the plants are stunted and flower prematurely, and the yield is always low. If, on the other hand, the land is broken up as soon as the rains break, at the end of March or early in April, and the cotton is not planted until towards the end of May or early June, normal growth and good yields result. The photograph demonstrates the effect of the two 'treatments' described above on cotton at the Serere Experiment Station in 1935. At the left of the picture the cotton is stunted and yellow; at the right it is normal.

"The history of this crop is of interest. A new block was cleared from bush and planted with *Stizolobium* at the end of 1934. Early in 1935, when the time came to turn in the *Stizolobium*, prior to planting the cotton experiments, it was found that the block had not been properly squared off. The still virgin land required to complete the area was ploughed for the first time just prior to the cotton planting. The photograph was

taken at the line where this virgin land abutted on that previously planted with *Stizolobium*.

"This effect has been recognized for some time past. When a new system of cropping was inaugurated in 1933, the following rotation for the seed-farm areas was adopted: —

First Year—
Late rains.—Land cleared from bush and *Stizolobium* planted.
Second Year—
Early rains.—*Stizolobium* turned in; cotton planted.
Third Year—
Early rains.—*Eleusine* and groundnuts.
Late rains.—Grasses planted.
Fourth and Fifth Years—
Under grass.
Sixth Year—
Late rains.—Land reopened and *Stizolobium* planted.

"In the Eastern and Northern Provinces of Uganda, cotton is almost always the first crop to be planted on newly cleared land. The wimbi crop (*Eleusine*) is normally broadcasted into the standing cotton before the break of the rains, and is therefore the second crop in the native 'rotation'. Certain natives plough up virgin soil before the dry season commences; on these plots they usually plant cotton as first crop, but in some exceptional cases I have seen wimbi planted as a first crop. I can only suppose that in the latter cases the native is aware of the phenomenon described by Mr. Rounce. It should be noted that in the areas of savanna bush and light soils, wimbi is hardly ever planted in the late rains.

"Some trial plots have already been planted with cotton at a few centres in Teso District (of the Eastern Province) to compare the following treatments: —

(*a*) Ploughed before the dry season and again after the break of the rains prior to planting cotton.
(*b*) Ploughed as soon as the rains break and a second time prior to planting cotton (this is the normal good native practice).
(*c*) Ploughed once immediately before planting cotton.

The results of these experiments will not be available until harvesting of the cotton crop is completed during February, 1937.

"Mr. Milne's second case of the 'over-oxidized and sheet-eroded soil' is a very good description of the soil throughout large areas of the Eastern and Northern Provinces of Uganda. Mr. Milne states that the act of tillage stimulates the non-symbiotic nitrogen-fixing organisms to activity, and their multiplication depends on supplies of energy-yielding carbohydrate, which, he suggests, might be supplied by the root residues of two or three seasons' legume and tuber crops. Under Teso conditions, however, there appears to be a sufficiency of carbohydrate from the roots of the grasses and small trees and shrubs which are turned in when the land is ploughed for the first time. A time lag is required, however, before nitrogen becomes available for plant growth, and in our experience it would appear that this time lag is not so prolonged as in the cases quoted by Mr. Rounce, presumably because our conditions are less arid than those ruling in many parts of Tanganyika."

The Grey Field Mouse

By W. VICTOR HARRIS, *M.Sc., F.R.E.S., F.Z.S., Entomologist, Department of Agriculture, Tanganyika Territory.*

Injury to crops in the field by rats and mice is not uncommon in Tanganyika. House rats and field rats are an annual pest in the natives' grain fields. The grey field mouse has become widely known owing to its habit of feeding on the seeds of ripening cotton and its ability to appear in the fields in large numbers, causing spectacular havoc.

The adult of the grey field mouse, *Mastomys coucha*, is from four to five inches in length, with a tail about half an inch shorter (Fig. 1). The males are on the average larger than the females. The body is covered with soft fur, dark grey to brown above and pale grey below. The tail is clothed in fine dark scales and short pale hairs. The female has from fourteen to eighteen teats arranged in two continuous rows along the abdomen, a feature that explains the name, "multimammate mouse", which is also given to it. This mouse is distributed in its various local races from the Cape to Morocco. It is a true field mouse, inhabiting bush country as well as cultivated areas, though driven by lack of food into grain-stores and dwelling-houses at certain seasons. It is nocturnal in habit.

Attention was drawn to the grey field mouse by its increase in numbers in certain seasons in the Kimamba area of the Eastern Province, a centre of European cotton-growing, culminating in the "plague" of 1930-32. 1931 was the peak year, and the infestation then spread as far as Morogoro, over 40 miles away. Observations showed that there was a definite migration of field mice into the cotton areas, and not merely an abnormal increase of the local population. In fact, there appeared to be a decrease in the other rodents.

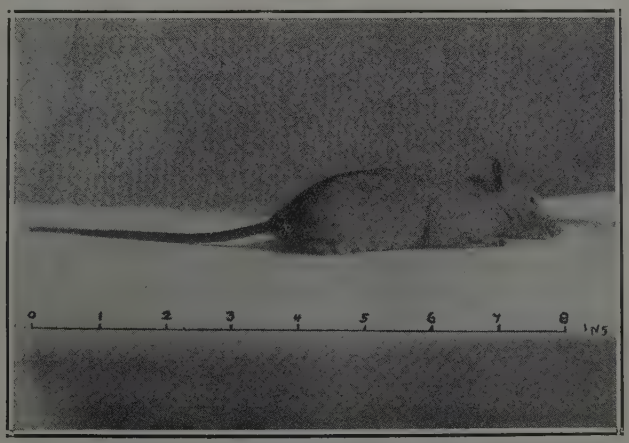


FIG. 1
The Grey Field Mouse (*Mastomys coucha*); young female

The prevalence of the grey field mouse depends on two factors: —

(*a*) Seasonal fluctuations in the resident population.

(*b*) Influx of migrants in more or less regular cycles over a number of years.

In the Morogoro district, the activities of the resident population are least during the months of January to May; that is, during the periods of greatest heat and rain, in the interval between the germination of the grain crops and the ripening of the maize. During this time the field mice inhabit deep and intricate burrows in the earth, many of the burrows containing stores of grains and legumes. The majority of the mice at this time appear to be young and in good condition. About the beginning of March the reproductive organs of both sexes become mature, and pregnant females and litters of young are soon to be found in increasing numbers. Powell (1) in South Africa says that this mouse begins to breed at the age of three months, and that there are from twelve to twenty young in a litter. In Tanganyika, I have never found more than eight young in a nest or embryos in a female. With the harvesting of the maize crop in April and May, field mice are more in evidence in the fields. Their numbers increase to a maximum in July and August, as the sorghum ripens. They are then forced into the cotton, where they climb the plants to reach the open bolls and feed on the seeds. In the process, lint is pulled to the ground, soiled, and generally spoilt (Fig. 2). There is also a considerable loss in weight of crop, due to the destruction of seeds, as well as loss in quality. Unopened fruits are next attacked, and even the stems of the plants are gnawed. There is no doubt that the slightest procrastination of the part of the cultivator to pick his cotton greatly facilitates the work of the mice. As the cotton is picked and the bush is burnt, there is a reduction in numbers of the mice. In October and November they may appear plentifully in dwelling-houses for a short period. With the short rains in November the planting of grain begins again, and the mice feed on the seed and on seedlings up to a height of five or six inches.

FIG. 2

Effects of Field Mouse attack on Cotton

Through the co-operation of the Medical Officer and Sanitary Superintendent of Morogoro, I was able to study the fluctuations in numbers of rodents during the two years from December, 1931, to December, 1933. These studies were based on trappings made by the Health Department in fields and gardens around the borders of the township, and may fairly be regarded as a reasonable indication of the rodent population of open cultivated fields.

The monthly catches of grey field mice accord with the account of their behaviour given above. The most striking feature was a fall from a catch of 170 mice in December, 1931, to 20 in January, 1932. This point probably marks the end of the immigrant invasion of 1931; thereafter the fluctuations in both 1932 and 1933 were those normal for the rodent population—a drop to a minimum in February and March of each year, followed by a rise to a maximum of 40 in June, 1932, and in August, 1933.

The migration of large numbers of field mice from the bush into cultivated areas is a phenomenon well known in certain localities to occur at intervals of a few years. Reports of such "plagues" have been received from the Southern Province near the Rovuma River, and from the country bordering on Lake Ruka. I have encountered a migration of considerable numbers of mice during the night near Nzega, in the Western Province. In the Kimamba area, already referred to, field mice were numerous in 1925 and 1926. They appeared again in 1930, reached a maximum in 1931, were fewer again in 1932, and absent in 1933. During the present year (1936) they have again appeared, indicating a cycle of from four to five years. The migrations begin early in August, when the mice invade the fields of ripening sorghum, augmenting the local population already at work. They are most in evidence later, when they turn to the cotton. The commencement of grass-burning appears to aggravate the situation. During this time, breeding proceeds rapidly, the mice digging shallow holes in the fields, particularly in sheltered banks or under sisal hedges. The sudden decrease in numbers during December, 1930, and January, 1931, was striking. There were no signs of an epidemic disease, however; no dead bodies were to be seen, nor were unhealthy specimens found among the collections. In no year have any indications of a return migration been found, such as progressive reduction in numbers towards the focus of infestation or an actual mass movement of the mice.

Kimamba lies on the north-western edge of a large grassy plain. It is the nearest settlement of any size to an extensive swamp area from which the migrations of mice are believed to radiate. Only when the migration is at its height, as in 1931, do the mice affect the other more distant settled areas around the borders of the plain, such as Kidodi in the south and Mlali in the west, between thirty and forty miles away.

Control.

The grey field mouse has many enemies, in the civet cat, genet, birds such as the owl, falcon and eagle, and snakes, but they appear to exert little influence during migration years. It is the host of numerous parasitic worms, but they do not appear to impair its vitality. The causes of the rapid decrease in numbers after a migration remain to be discovered.

For the protection of crops, both from the normal resident population and from migrants, trapping and baiting are necessary. Trapping is laborious, and better suited to the protection of grain-stores,

cotton-stores and houses. Baiting on a large scale is more practical. The most satisfactory bait contains barium carbonate. Other poisons, such as arsenic and strychnine, are effective, but their use on a large scale is risky. Directions for their use are to be found in Entomological Leaflet No. 12.(2)

Barium Carbonate Bait.—This is prepared by mixing either maize meal or sorghum meal with barium carbonate in the proportion of 3 parts of meal to 1 part of poison. Complete mixture and crushing of lumps is essential. Water is then heated—four pints for 5 lb. of maize meal (machine ground) and four pints for 8 lb. or sorghum meal (native ground)—and the mixture added to it slowly, with constant stirring. After all the meal has been added, the mixture should be a thick porridge. It is then cooked for a few minutes, with vigorous stirring to prevent burning. This cooking is necessary, since otherwise the cakes of bait crumble when dry and cannot be bagged. The mixture is then allowed to cool, and moulded by hand into balls of about half an ounce. Such balls contain about fifty grains of barium carbonate, or approximately twenty lethal doses. Sorghum flour makes the more durable bait, and may be made into small cakes by partial drying in a thin (¼ in.) layer and then cutting up into ½ in. squares. These pieces, when thoroughly dry, weigh about twelve to the ounce, and so contain three lethal doses. Six to eight hours of strong sunshine is sufficient to dry the bait, after which it can be bagged and stored. If properly dried, the bait can be stored for two months during the rains. Mould is absolutely fatal to its efficiency. Attractiveness is increased if the cakes can be coated with a little vegetable oil immediately before distributing. The addition of ordinary laundry blue, at the rate of one tablet to four pints of water used, is useful in rendering the bait more easily identified in the stomachs of dead mice.

Bait remains attractive for a longer time in the field if sheltered from the sun and rain. Small grass shelters at known points are additionally useful in that observations on the amount of bait taken are easily made, and a system is introduced into the campaign. A systematic procedure in baiting against rodents is desirable under any circumstances, but against field mice it is essential if it is to be an economic success. The campaign for the protection of cotton fields should be organized and put into operation before the mice actually enter them. Local knowledge of the habits of the mice is useful in estimating the probability of a serious increase in the local population and in recognizing a migration in its early stages. The rapid clean-up of grain fields after harvest and the rat-proofing of grain stores, coincident with the first distribution of bait, is essential if the mice are to make full use of the bait offered. Similarly, pressure should be brought to bear on the indolent cotton-grower who delays in picking his crop.

REFERENCES.

(1) Powell, W., 1925.—"Rodents." Union of South Africa, Dept. Public Health.

(2) Harris, W. V., 1934.—"Rats and Mice." Tanganyika Dept. Agric., Ent. Leaflet No. 12.

Mixed Farming in East Africa

IV.—The Value of Native Stock

SOME NOTES ON BARATON INVESTIGATIONAL CENTRE, NANDI, AND THE BARATON HERD OF NANDI CATTLE.

By H. C. W. GUY, *Dip. Agric.* (*Potch.*), *Instructor in Stock, Department of Agriculture, Kenya Colony.*

The view has been expressed, not infrequently, by eminent authorities in South Africa, that it is a matter of extreme regret that so little attention has been paid in the past to the improvement and development of the indigenous cattle of Africa.

It was not until 1929 that policy was formulated in Kenya Colony for the improvement of indigenous cattle and for the collection of data from the various types of cattle in East Africa.

It has been the endeavour in this article to set out in concise form the preliminary data, collected at the Baraton African Investigational and Training Centre, in relation to the milking propensities of the Baraton herd of Nandi cattle, with a short preface indicating the uses of native cattle in the system of mixed farming.

The intention is not to enter into a long preamble on the controversial subject of grade *versus* native cattle, but it is felt that a study of the results obtained at Baraton should be of assistance to the farmer contemplating dairying in a small way.

Where the price of land is reasonably low, and the output per acre is much lower than in the recognized areas of more favourable dairying potentialities, wherever conditions for grazing are not "kind" or where disease is prevalent, the introduction of a selected herd of native cattle should be seriously considered as providing the best prospect of profitable dairying.

It has been demonstrated in the investigational work at this centre, the results of which are given in the latter portion of this article, that under proper management the native cow, on natural grazing, is not only capable of producing a fair amount of milk of exceedingly high butterfat content, but also of retaining a good milk flow over a lactation of quite normal duration.

Where it is not possible to supply whole milk for liquid sale and the milk has to be converted into butterfat, which is saleable at a relatively lower figure, it is not economical to practice heavy concentrate feeding in areas of this kind, and, in any case, it is shown that the native cow is a good butterfat producer on natural grazing.

A first-class native cow will produce approximately 150 to 180 lb. of butterfat per lactation period. When it is realized that a good grade cow will only produce a similar quantity, the position may be summed up by saying that a first-class native cow is equal to, if not better than, an average grade cow.

Furthermore, a fact of particular significance in this connection is that some farmers in the lower rainfall areas, where dairy ranching is carried out with grade cattle, have been compelled to revert to the use of low grade or native bulls, in order to return to a standard nearer the native and so to bring back lost constitution and resistance to disease.

It will be admitted readily that the comparatively small, light-boned and

"Baraton arap Cheboit". Dam No. 11
Age 3 years 9 months

"Arap Chepsietje". Dam No. 5. Age 17 months

"Arap Chapkarrai". Dam No. 57. Age 2 years 3 months

"Baraton Bendu". No. 10. Best lactation 3026 lb. in 297 days. Average butterfat 5·1%

"Baraton Chepsietje". No. 5. Best lactation 3041 lb. in 311 days. Average butterfat 6·4%

"Baraton Chapkarrai". No. 57. Best lactation 3024 lb. in 291 days. Average butterfat 5·0%

hardy native cow requires less attention, less feeding, and less mineral supplement than the larger and bigger-framed grade cow. The farmer with limited experience in the raising of stock should find no difficulty in maintaining a herd of native cattle in flourishing condition and in full production.

The one-crop farmer, with a leaning towards dairying and stock-raising, and with a desire to transfer some of his eggs from the one and only basket, might be well advised to study the suitability of introducing, as a side-line, or as a commencement of mixed farming, a small herd of native cattle. There is much to be gained by such a step, and little or nothing to be lost. At the very least, he is assured of a supply of hardy young oxen for draught purposes, and of a valuable supply of farmyard manure to maintain or restore the fertility of his soil. On the other hand, a herd of native cows, properly managed, should show a reasonable profit, with a valuable augmentation to the farm budget.

Arising out of a visit to the Ngong African Veterinary Training Centre by the elders of the Nandi Local Native Council, representations were made for the establishment of a similar institution in the Nandi Reserve.

Some 350 acres of land were made over to the Department for the purpose of carrying out investigational work in relation to the milking propensities of the Nandi native cattle, and for the establishment of a training centre, where educational facilities in animal husbandry were to be provided for young men of an advanced standard of elementary education.

In April, 1930, work was commenced, and the total area was completely ring-fenced. Since then, development has proceeded along sound lines, and to-day excellent facilities are provided for the training of pupils; in addition, many preliminary data have been collected which clearly establish that, of all the types of cattle indigenous to East Africa, the Nandi cattle rank very high as milk producers, when judged by the ordinary standards of native stock.

History.

Nothing is known of the origin of the Nandi cattle. They are descendants of the *Bos sondaicus* group. The present-day cattle have developed under ideal conditions. The Nandi Reserve chiefly ranges over 6,000 feet above sea-level, and has an abundance of luscious grazing. The average rainfall is about 60 inches per annum, and the distribution is fairly even, with a falling-off of rain in the months of December, January and February.

Before the advent of a civilized administration, the Nandi warriors carried on their predatory cattle raids on the adjacent tribes. The best cattle obtainable were introduced into their own herds. By this constant influx of fresh blood, the type was kept invigorated, and the risk of uncontrolled inbreeding, with its devitalizing results, was greatly diminished. This state of affairs, combined with a good knowledge of management and a favourable environment, have done much to produce the present-day type of Nandi cattle.

The Nandi red cow was spoken of very highly as a good milk producer by the early settlers of the Uasin Gishu, but whether the red cow surpasses the black is not clearly established.

Some 60 head of cattle were originally purchased from the Nandi as a foundation herd. These cattle were selected at random, no preference being made as to colour or conformation. Not a wide range of choice was offered. In-calf heifers were

brought in for sale, and were purchased if patently sound; if not, they were rejected.

No definite scale of points has yet been followed in selective breeding, as the Baraton milch herd is still in an experimental stage; but on the whole the herd shows very definite characteristics to type, but not to colour. It is probable that plain black and plain red predominate, although all combinations of colour are encountered.

Management.

The rationing of the milch herd consists of pasture grazing. Hay and maize silage are liberally fed during the dry weather months. No attempt is made to feed concentrates on a maintenance and milk production basis.

Cows are brought in for hand service during periods of oestrum.

Cows and heifers are given the choicest grazing prior to calving and when in milk.

Udder manipulation and massage is practised to induce normal flush and to accustom young heifers to handling and milking.

The milking routine of the herd is as follows: 6 a.m., morning milking; 4.30 p.m., evening milking. No additional milkings are given, not even to advanced yielders.

It has been the endeavour in this article to illustrate by graphs the milking capacity of the Baraton herd, rather than to give detailed records of each cow. It was not until 1932 that systematic and methodical records were introduced, and Fig. 1 illustrates the increase in production in terms of pounds per cow-day for the years 1931-32 and 1935.

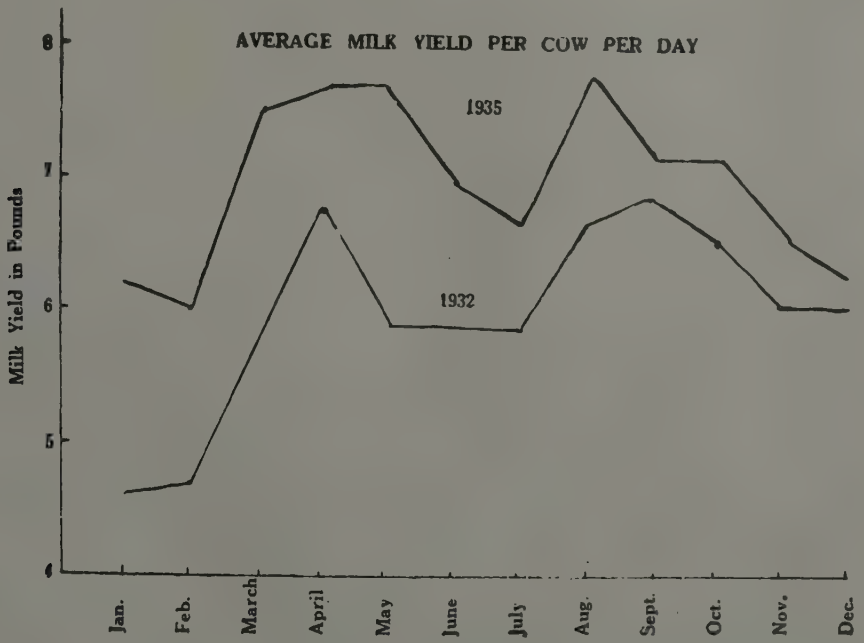


Fig. 1

Rainfall for 1932 amounted to 50.38 inches, with a generous distribution between March and September. 1935 recorded 51.29 inches of rain, with a very similar distribution. The difference in rainfall is so small in the two years under comparison as to be discounted.

Fig. 1 illustrates the increase in milk yield in March-April, following favourable rains and a flush of palatable young grass, with a falling-off in November-December-January, when rainfall is at a minimum.

Fig. 2 illustrates the milking capacity of the Baraton milch herd, taken from the first lactation records in 1931-32. It will be noted that 31 cows, or 62 per cent, are classified as low producers of under 1,500 lb. in the first lactation.

Fig. 3 represents the herd chart for 1935.

A comparison of the two figures clearly illustrates the improvement which has taken place since 1931-32, and demonstrates the advisability of retaining cattle until their second and third lactations are completed before culling.

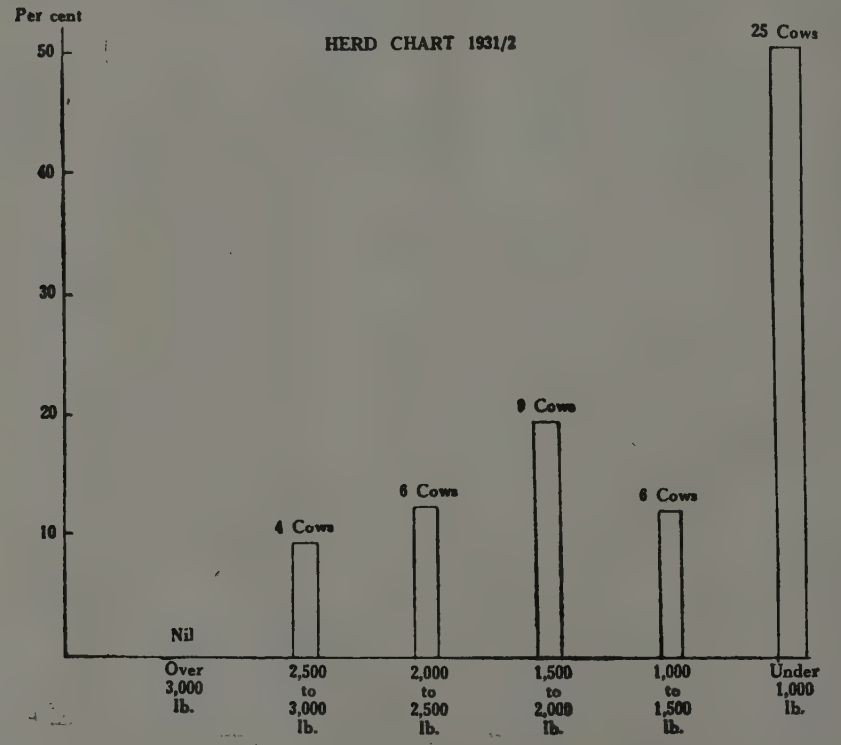


FIG. 2

In some instances, cows classified in the "under 1,000 lb. class" in Fig. 2 have been transferred to the "over 2,000 lb. class" in Fig. 3. The "under 1,500 lb. class" has been reduced to 22 cows, or 44

per cent. The same 50 cows are represented in each figure.

Progeny Heifers.

It may be of interest to give in detail records from heifers bred on this station from foundation stock.

MILK PRODUCTION OF NANDI HEIFERS BRED ON THE STATION FROM FOUNDATION STOCK

Heifer No.	Days in Milk	Lactation	Total Yield per Lactation	Butterfat Per cent
			lb.	
62	238	1st	1301	6·0
	296	2nd	1638	5·8
63	230	1st	1759	5·9
	183	2nd	827	5·2
	315	3rd	1736	5·6
64	—	1st	—	—
	—	2nd	—	—
65	—	1st	—	—
66	218	1st	962	7·0
	148	2nd	945	6·3
	229	3rd	1097	6·2
67	236	1st	1289	6·2
69	261	1st	1659	6·5
	279	2nd	2150	6·5
	324	3rd	1977	7·0
70	151	1st	747	6·6
71	202	1st	910	6·6
72	161	1st	441	5·6
	219	2nd	1059	6·7
73	301	1st	1650	6·5
74	288	1st	1692	6·1
75	253	1st	1008	6·7
76	278	1st	2409	6·0
77	237	1st	1138	6·6
78	34	1st	229	5·3
81	255	1st	2342	5·5
84	231	1st	1278	6·9
87	256	1st	2214	6·1

It will be observed from an examination of the above table that heifers 76, 81 and 87 are of outstanding merit and show very definite milking propensities.

Calves.

There is no weighbridge at this station, consequently no records of weight for age exist beyond the weaner stage.

Birthweights are taken and calves are subsequently weighed each week until 26 weeks old.

The following statistics are taken from the 1935 recordings:—

Average birthweight of—	*Lb.*
13 calves from heifers calving for the first time	37.5
5 calves from heifers calving for the second time	39.8
8 calves from cows calving for the third time	39.1
13 calves from cows calving for the fourth time	41.0
9 calves from cows calving for the fifth time	42.0
6 calves from cows calving for the sixth time	44.0

	Lb.
The average weight of all calves at 26 weeks of age	188
The average birthweight	40.4
The average daily gain in weight ...	0.80

Summary.

A brief summary of the workings of the year 1935 may not be without interest.

The milch herd strength amounted to 73 cows in 1935.

54 cows calved down during the year. Of the 54 calves born, 35 were reared (22 heifer and 13 bull calves); 11 bull calves were slaughtered at birth; 5 calves were slaughtered later, on account of milk shortage; 3 calves died.

A total milk yield of 76,699 lb. was obtained from an average of 29.7 cows milking per month, giving an average yield of 7.03 lb. per lactating day.

60,866 lb. milk was separated for the manufacture of butter and ghee.

60,866 lb. milk	=	4,408 lb. butter
13.8 lb. milk	=	1 lb. butter
4,408 lb. butter	=	3,394 lb. ghee
10 lb. butter	=	7.7 lb. ghee
18 lb. milk	=	1 lb. ghee

The average percentage butterfat con-

tent for the year 1935 worked out at 5.6 per cent.

The foregoing is a summary of the preliminary data which have been collected from the investigational work carried out at this centre, and tends to demonstrate the inherent potentialities of the native stock.

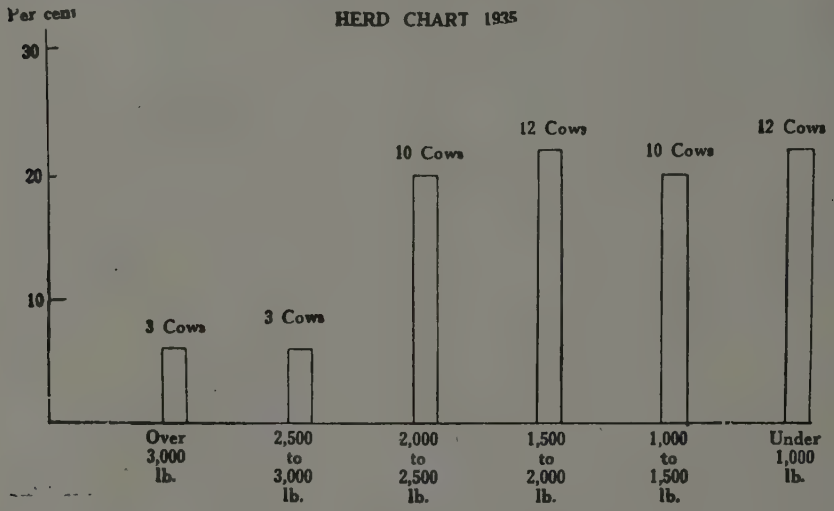


FIG. 3

Pyrethrum Drying

By V. A. BECKLEY, *M.C., M.A., A.I.C., and* F. MCNAUGHTAN, *B.Sc. (Hons.),*
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When first the subject of the artificial drying of pyrethrum was raised, the only information available was to the effect that drying at a temperature of 40° C. (104° F.) caused no loss of pyrethrins. Accordingly, it was recommended that drying-houses should be run at temperatures between 100 and 105° F. For various reasons, discussed below, drying was very slow, and soon higher temperatures were being employed. Drying-houses run at over 150° F. have been visited.

A search of the available literature has given meagre results. In the second edition (1936) of Gnadinger's exhaustive book on *Pyrethrum Flowers,* it is still stated that in Japan artificial drying at a temperature of 65° C. (149° F.) is sometimes used. Only one experiment referring to the effect of heat is quoted, and here temperatures of 100° C. (212° F.) were employed. It was thus desirable that the subject be investigated, and a series of experiments was undertaken. The results are not given in detail here—only the conclusions.

Quick drying in the sun did not affect the pyrethrin content, but prolonged sun and shade drying caused appreciable losses. Drying artificially at temperatures up to 50° C. (122° F.) did not affect the pyrethrin content. At 60° C. (140° F.) there was a small but appreciable loss. Increasing temperatures caused an increasing loss of pyrethrins.

Colour, too, is affected by the method and temperature of drying. Up to 120° F. the colour of the dried flowers was bright, the receptacles green, the ray florets pure white, and the disc a clean, clear yellow. Drying at 140° F. caused some discoloration of the rays and the receptacles. Above this temperature discoloration increased, the product at 212° F. being very brown. Sun-drying in clear dry weather gave a fine product, except that the receptacles were rather bleached. Prolonged sun and shade drying, in dull weather, produced very dingy flowers. Prolonged artificial drying with bad ventilation discoloured the flowers considerably.

It is strongly recommended that the temperature in drying houses must not exceed 130° F.; it would be preferable if a maximum of 120° F. were not exceeded.

The first type of drying-house to be used on any scale was the oast house, based upon a coffee drier designed by Mr. A. Barnley, of Thika. Briefly it consists of an inverted, truncated oblong pyramid in which are heating braziers arranged along the length of the base. Above this is the drying floor, which usually has a thatched roof. Heating is by means of open charcoal braziers. Usually the flowers are placed on trays on racks on each side of a passage-way.

In the early stages of the industry these driers met the needs of the growers; but, with increasing acreages, their defects became apparent. Drying was slow, and the fuel consumption was high. In response to numerous complaints, a survey of a number of these driers was made.

In most cases expense of construction was an important matter, and so the walls were made of wattle and daub. In drying, the plain puddled earth, usually ordinary red earth, had cracked, providing innumerable channels for cold air to

enter. Naturally, it was difficult to maintain the desired temperature, and consequently the braziers were stoked up until flames shot feet above the top of the brazier. If there was any breeze, the draught became sufficient to move the flames about, and in one case so strong was the wind that the flames were playing on one of the side walls. Certainly this explains how some of these oast houses have been burnt down. It is evident that better construction, and lining the walls, will reduce heat losses and fuel consumption.

The method of stacking the trays is manifestly inefficient. The draught through the thatched roof is strong. An unoccupied space in the middle of the building provides an escape for the hot air before it has done any work. Tests made in many oast houses showed that the air under the roof above the passage was hotter and drier, not only relatively but absolutely, than that passing over the trays. This could only be the case if the greater part of the hot air had done no work at all. It was also discovered that very little air passed through the trays. Most of the air that did not escape up the middle passage-way travelled in a nearly horizontal direction over the trays, inwards towards the passage. Should the bottom of a tray sag, the flowers below the horizontal plane did not dry.

It was suggested that trays should not be stacked flat on the rack, but at an angle of about 45° to 60° to the horizontal, giving a large number of upward channels between the trays for the air to pass. Where this recommendation has been followed, the efficiency of the oast house drier has been considerably enhanced. This method of stacking has certain disadvantages. It is, for example, difficult to find out if the flowers are dry and to remove trays of dry flowers. A further suggestion for modifying the oast houses will be made when the Ainabkoi drier is described.

Another type of drier which is fairly popular consists of a long building, often roofed with corrugated iron, heated by a couple of flues running the whole length of the building. Flowers are dried on racks over the flues. Here, too, there is a central passage-way. Very often ventilation in these driers is restricted, and it was feared that flowers in such driers would be stewed rather than dried. On the contrary, it was found that many of these driers were efficient, the charge drying in 24 to 36 hours, while the expenditure on fuel was comparatively low. A study of these apparently insufficiently ventilated drying-houses showed that there was a considerable movement of air inside the building. The partly saturated warm air rose to the roof, where it was cooled sufficiently to sink to the floor-level to be re-heated, and so do more work, thus economizing in the consumption of fuel. The continuous movement of air maintained a flow of warm air over the drying flowers.

Consideration of the subject of drying from the theoretical aspect shows how great the saving in fuel may be.

1 B.T.U. (British Thermal Unit) will raise the temperature of 4.2 lb. of air through 1° F., and will be given up on cooling the same weight through 1° F. Assuming that air reaches the flowers at a temperature of 120° F. and is cooled to 110° F., then in cooling each pound of air will give up $10/4.2 = 2.38$ B.T.U. Every pound of water heated from 60° F. to 110° F. and evaporated at that temperature at a barometric pressure of 23 in. of mercury will use 1050 B.T.U. If 75 per cent of the weight of fresh flowers is water, then each pound of flowers in drying will use $\frac{1050 \times 75}{100} = 787.5$ B.T.U. This amount of heat will be supplied by 331 lb. of air cooling through 10° F. To heat this amount of air from 60° F., a normal air temperature, to 120°

F. will need 4730 B.T.U. Should partially saturated air at 100° F. from the top of the room sink to the floor and be re-heated to 120° F., then only 1576 B.T.U. will be required.

That is, the circulation of the air, under the conditions postulated, means a reduction of the fuel to one-third.

It may be thought that this amount of air will not suffice to carry away the water evaporated from the flowers. Assuming that the cold air entering the drier is saturated at 60° F., each pound carried 76.5 grains of water—such a condition will be quite common. Air at 110° F., when saturated, carries 415 grains of water per lb., but never in a proper drying-house is this condition attained—a degree of 40 to 60 per cent saturation being usual. Taking the lower figure, the air is holding 166 grains of moisture in each cubic foot, i.e. it has taken up 89.5 grains of water. Now each pound of wet flowers has lost 5,250 grains of water, or the amount taken up by 58.7 lb. of air, roughly one-sixth the amount of air needed to supply the quantity of heat necessary to evaporate the water.

If another line of calculation be taken, a better idea may be obtained. Assume that the air entering the oast house through the braziers is saturated with water vapour, and that all of the air passes over the flowers and does useful work in dropping through a temperature of 10° F. to 110° F. To dry 1 lb. of flowers, it has been shown, requires 331 lb. of air under the conditions postulated. These 331 lb. of air carry off ¾ lb. or 5,250 grains of water, or each lb. carries off 15.8 grains. As air saturated at 60° F. contains 76.5 grains of water per lb., the total amount of water in the hot air at 110° F. is 92.3 grains per lb. Since saturated air at 110° F. holds 415 grains per lb., the relative humidity of the waste air in an efficient, carefully controlled drier of the oast house type cannot exceed 22.5 per cent.

It must be remembered we have postulated a drop in temperature of 10° F., i.e. from 120° F. to 110° F. In practice, greater temperature differences between top and bottom have been observed, so that the maximum humidities may be much higher. In a very efficient type of through-draught drier the escaping air had a humidity of 39 per cent. That in many ordinary oast house driers was of the order of 25 per cent. The lowest observed was running at a temperature of 150° F., where the relative humidity of the waste air was well below 20 per cent; it was too uncomfortably hot to take full readings.

In the flue-heated buildings, where there is a circulation of air due to convection currents, a higher relative humidity can be expected. In one, in which the flowers were dried in two shelves above the flues, the relative humidity above the flue was about 40 per cent, and above the shelf 55 per cent. In another, heated by steam pipes, with flowers on shallow trays, angle-stacked about 30° from the vertical, it was impossible to measure the humidity of the air before it reached the trays, but that escaping at the top had a relative humidity of 61 per cent. Here the downward current to the heating space was sufficiently strong to draw the flame of a match downwards. From these figures it is evident that there had been repeated re-circulation of the warm air. Instead of cold air being heated through a temperature of 60° F. the warm air was being heated through 20° F., which would give a fuel saving of two-thirds.

It would appear that this type of house is the best. Certainly it is efficient; but, in most cases, the efficiency is accidental, the proportions of the building being suited to the convection currents. The

writers would not attempt to design such a building. The balance between the incoming cold air and the escaping warm air needs also to be carefully adjusted, or efficiency is lost.

So far only the successful houses of this type have been described. One was inspected in which the ventilation was very poor. The air inside was nearly saturated, and drying took 10 to 15 days. It is not surprising that the flowers from this drier were always under grade. In yet another, the flues were of galvanized piping, 4 in. in diameter, the flue was led from the fire-box under the trays and then up and over the trays to the chimney. Here one-half of the flue was serving no useful purpose at all. On the contrary, the heating of the air above the trays was increasing the draught considerably and thus the heat losses.

In the theoretical discussion above, the loss of water was regarded as a question of simple evaporation, similar to that from a free water surface. In reality, it is much more complicated. Evaporation from fresh flowers is more rapid than from nearly dry flowers. In certain experiments made at the Scott Agricultural Laboratories a forced draught of air was used, the temperature of which, at the warm end, varied little from 50° C. Fresh and nearly dry flowers were exposed to the draught. The temperature in the wet flowers was about 32° C., in the dry 44.5° C., i.e. rapid evaporation had reduced the temperature of the wet flowers 17° C. (31° F.) below that of the air current, while the slower evaporation from the nearly dry flowers had reduced the temperature only 5.5° C. (10° F.). Roughly speaking, the loss of moisture was three times as fast from the wet flowers as from the nearly dry.

If trays of flowers are so arranged that air passes either over or through them successively, two possible arrangements can be made: either wet flowers can first receive the hot air or vice versa. In the former arrangement, the air will carry off moisture rapidly and the flowers will themselves be much cooler than the air. In the second system, the nearly dry flowers meet the hot air and their temperature closely approximates to that of the warm air; the wet flowers dry more slowly, since by the time the air reaches them it has been cooled somewhat.

The former method appears to be the better. Hotter air can be used without danger of the flowers being overheated. The rapid evaporation will give a greater temperature drop, and so a better utilization of the heat. The dry flowers, which are in a state when the difference between their temperature and that of the air will be small, are at a comparatively low temperature. One would therefore expect to be able to dry flowers more quickly and with more safety in this packing than in the other. This, in fact, is true for normal conditions, but unexpected troubles appear in practice. It is impossible, in commercial picking of pyrethrum, to pick nothing but fully mature flowers; with the greatest care, there will always be some immature ones. Under the former arrangement of trays (the flow parallel to the current), the rapid drying of the soft immature achenes develops over them a hard skin, impervious to water and water vapour. The consequence is that the immature flowers do not dry out. In one series of experiments, the mature flowers dried in 7 hours; the immature were not dry 24 hours later. Flowers started in the partially cooled air and moving towards the hot air, the counter-current flow, dried evenly in 9 hours. One point applicable to all drying systems arising out of these observations is that *fresh flowers must not start drying at high temperatures.*

These systems of making the air pass over or through trays of flowers successively appeared to us to be logically sound, and experiments were started. The system tried was on the counter-current principle. Hot air was forced under a stack of trays to filter through them all. Unfortunately the experiments were a failure. The forced draught of air took the line of least resistance, and so the flowers dried most unevenly. No simple means of obviating the difficulty was evident. The faults in this experiment will be discussed later.

A successful application of the system has, however, been made by Mr. R. O. Barnes on an oast house type of drier. This drier has been modified, and is described fully below as the "Ainabkoi Drier". In brief, the application consists in enclosing the rack of trays in a draught-proof box. The hot air must pass through all the trays. Trays of flowers are moved successively downwards against the current of warm air. In this drier, single trays of flowers took from 8 to 15 hours to dry, i.e. from the time when they were put in at the top with wet flowers till they were removed dry at the bottom. This time was considerably less than in most of the driers inspected, and moreover the temperatures were never excessive.

Why did this arrangement work when our own experiment failed? The first point is that the draught was better distributed and was less violent. Here there was no disturbance of the flowers on the trays; in our own, the strong draught tended to lift the flowers, thus leaving open patches. The trays were better built. In our own the wire tended to sag and so permit the flowers to accumulate in the middle. This is a very common fault. Trays must be so built that the bottoms are taut and level. For this reason, it is recommended that light coffee wire be used for tray bottoms. It is strong and can easily be stretched to give a good flat bottom. Under the proper loading of ¾ lb. of flowers per square foot, there is no danger of the wire sagging. These two factors alone were enough to account for the failure.

The Ainabkoi Drier.

The original drier of this type is of the usual inverted pyramid oast house type; in fact, it was adapted from an oast house drier by the construction of boxes to carry the trays. It has been modified to a square building to be heated by flues. Heating by means of charcoal braziers is highly efficient, provided the air inlets to the braziers are fitted with good dampers and the charcoal is properly burnt. In the original of the oast house type of drier, designed and constructed by Mr. A. Barnley, the braziers were properly fitted with dampers, and during a study lasting three days we found that the temperature could be closely regulated and maintained. In the majority of those inspected by us, the regulation of the temperature was very much of the "more or less" type. It is considered that it will be easier to regulate the temperature in a flue-heated drier with only one fire-box than with a series of braziers. Of course careless stoking will give enormous variations, the only way to obviate which would be a slow combustion stove or automatic stoking. If charcoal has been very well burnt there is no danger of smoke discoloring the flowers. But very seldom is such charcoal used. Usually, after the braziers are stoked up, the drier is filled with smoke. Good flues will keep out all smoke.

The type of flue that we suggest is 11½ inches in diameter and of galvanized iron. Such piping costs Sh. 1/50 per running foot in Nairobi, and the necessary "T" pieces Sh. 7/50. The flue

system shown in the diagrams would cost, together with piping and elbow for a chimney, about Sh. 105. Several driers have been seen in which 4 in. galvanized piping has been used. Such flues are never entirely satisfactory. The small surface exposed reduces the amount of heat radiated, and thus the waste gases leave the chimney at a high temperature. This leads to several more disadvantages: (*a*) the high temperatures tend to destroy the flues; (*b*) they increase the draught considerably; (*c*) the increased draught tends to increase the formation of a tar, which either chokes the flues or oozes out at the joints. All of these factors lead to increased fuel consumption.

Tar formation and deposition is a disadvantage in all flue-heated driers. For this reason an expansion chamber has been provided in the plan. This should be provided with a door—a flat sheet of galvanized iron bolted over the aperture serves admirably—to enable one periodically to remove any tar deposited. This system is employed in a model coffee drier at the Scott Agricultural Laboratories, and works admirably. Incidentally the fire needed to maintain the drier at a temperature of 110° F. looks ludicrously minute.

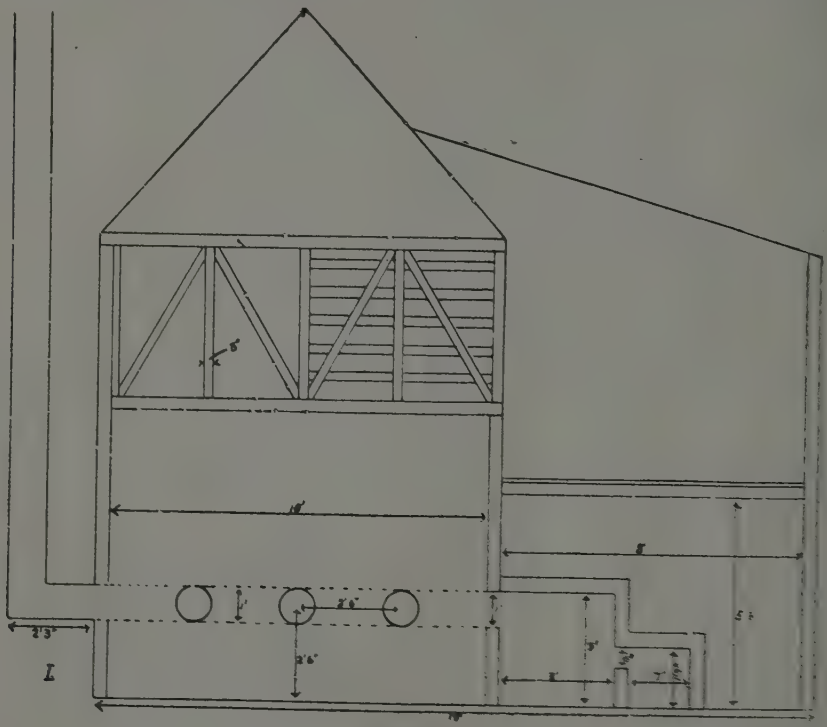

FIG. 1
Ainabkoi Pyrethrum Drier. Cross section

The system of successive use of the hot air further increases the efficiency of the drier. As the air passes through each layer

of pyrethrum it parts with a portion of its heat, vaporizing some of the water. The lowest tray, which is the driest, and so will part with moisture least readily, meets the warmest, driest air, while the wet flowers readily part with water to the cool, moist air. In order to obtain maximum efficiency, the trays, as the bottom one dries out and is removed, must be moved down one space, leaving the top space vacant for fresh flowers.

If, however, the system of filling the whole drier with fresh flowers and drying out the whole charge be followed, it will be found that the fuel consumption will increase, as also will the time of drying. A tray loaded at the rate of 3/4 lb. per square foot will have a layer a couple of inches thick; the same tray, when ready to be removed, will have a scattered layer of dry flowers. Air will pass slowly through the fresh flowers, parting with

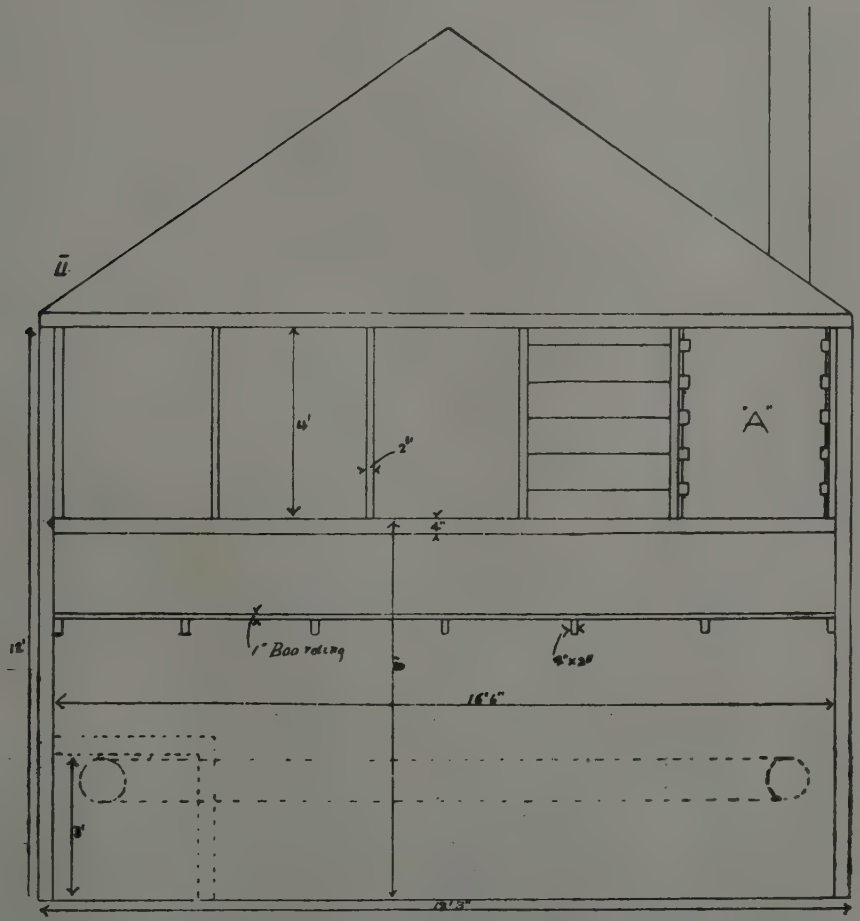

FIG. 2

Ainabkoi Pyrethrum Drier. Section through drying chamber

a good deal of heat, and as the flowers dry out so will the rate of passage of air increase and the heat transfer decrease. In the proper method of loading there is always some blanketing of the air flow; but, with the other, the obstruction will decrease as the charge dries and the velocity of the air will increase. The net result will be that more heat will be needed and the time of drying will be increased.

efficiency. In the diagrams the building is shown in ground plan and in two sections at right angles, together with details of one of the boxes.

The lowest part of the building is the firing and heating floor. In one part is the fire-box leading to the expansion chamber, out of which lead the flues. The fire-box is a two-foot cube externally and provided with fire-bars of iron and a door. The fire-bars are necessary to

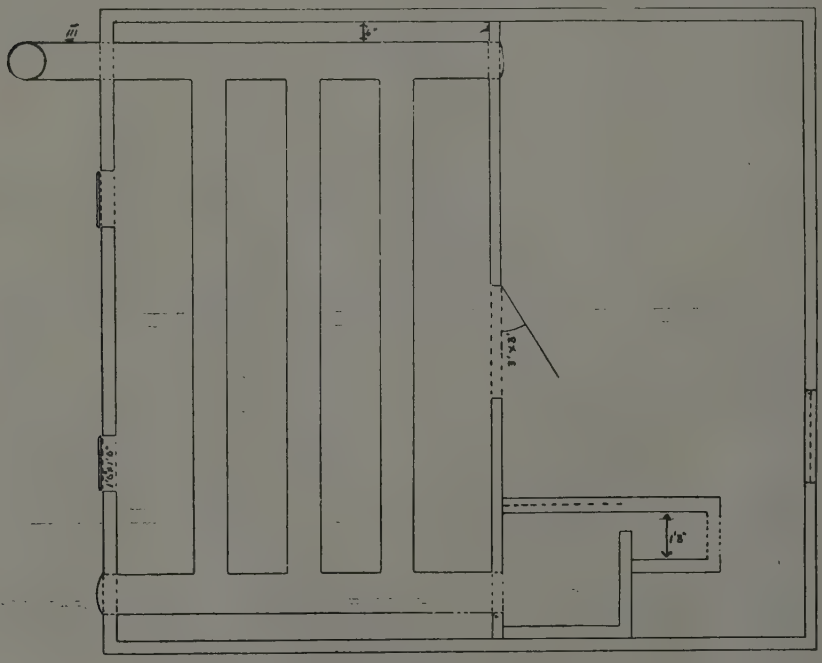

FIG. 3

Ainabkoi Pyrethrum Drier. Plan of heating and firing

Having discussed these points in the principles of the drier, we give the description in detail. A square building is required, preferably of stone or brick, although any other suitable building material may be used, provided airproof walls are made, since any leaks of cold air above the flues are sure to reduce the obtain as clean a fire as possible; building the fire on the bottom of the fire-box will simply lead to inefficient burning and heavy tar production. The door is simply a sheet of flat, heavy gauge, galvanized iron, and is needed to regulate the draught. The expansion chamber is 3 feet each way internally. The entrance

from the fire-box is as far as possible to one side, as shown in the diagrams, and the exit to the flues on the other side. This is done to increase the deposition of tar. As mentioned above, the expansion chamber is provided with a door for cleaning.

The flues are arranged as shown in the plan, the centre line of the pipes being 2 ft. 6 in. above ground level. It is advantageous to have dampers at each of the "T" pieces to adjust the distribution of the draught in the flues to get even heating. Leading from the firing compartment is a door to allow of entrance for adjusting the dampers. The bottom 18 inches of the door is separate from the top half, to allow the air to enter below the heating flues. In the outer wall opposite are two more ventilating apertures, 18 inches square, also fitted with doors. Temperature regulation is obtained by adjustment of the fire and the ventilation.

Above this is the charging and drying floor. Since this is several feet above ground level, it will be necessary to provide a ramp or a staircase for carrying in the trays of flowers (not shown in the plans). The smaller compartment which is shown in the plan is 8 ft. x 16 ft. 6 in. internally, but may, if desired, be made wider; this is the charging room. It is advantageous to have a charging room in order to protect the flowers and to save heat.

A very useful adjunct, seen in the original, is an unloading trough. Usually the dry flowers are scraped off the tray by hand, being partially crushed in the process and a portion lost. The unloading trough saves this, and costs little. It is simply a sheet of boards about 3 ft. 6 in. wide, inclining backwards, with a simple 1 ft. trough at the bottom. The length is about 8 ft. One end of the trough is closed. Near the other end is cut a hole, around which and below the trough are nailed four pieces of 2 in. x 1 in. board, to which the paper pyrethrum bag can be attached. One side of a tray of dry flowers is dropped into the trough and the tray reversed against the sloping back. The flowers fall into the trough, and are simply pushed to the hole and thus into the bag.

The charging room and the firing room, if floored at one end, are suitable for the storage of dry flowers, being warm and dry.

The drying floor is more complicated. In the plan, provision is made for five "boxes" to hold the trays. Each tray compartment is slightly over 3 ft. wide, to take trays 3 ft. wide, the width of coffee wire which is recommended. In the plan the space is shown as 3 ft. As five such boxes are provided for, the total length of this compartment is 16 ft. 6 in. It is difficult to describe the construction of these boxes properly; the writers are chemists, not engineers. However, an attempt will be made. The division between the boxes and the end pieces is made of 3 in. x 2 in. stuff, braced as shown in the diagram of the cross section. On this framework the runners, also of 3 in. x 2 in. stuff, are fixed. The lower pair afford a powerful support to the upright. In the larger scale drawing of this it will be noticed that the runners are spaced 6 in. apart; this space has been allowed because of the tendency for most timber in Kenya to warp. If well-seasoned timber or shallower trays are used the spacing can be less.

It is difficult to keep trays from sliding off the square and jamming against the uprights; therefore the space between the runners is closed with 3/8 in. or 1/2 in. stuff to form guides. Each tray compartment is thus a box closed on three sides. In order to prevent hot air escaping at the front end, the space between the

trays is closed with lengths of 3/8 in. or 1/2 in. stuff hung from nails in the runners. The whole box is closed with a light door, hinged from the top. To keep the door open when moving trays, a piece of wire bent into a hook is ample.

[*Photo. J. F. Barnes*
Photograph of the interior of the original Ainabkoi Drier (See "A" Fig 2)

The roof of the drying compartment is complete, being high-pitched to give a strong draught. The roof of the charging room is a lean-to upon this. Thatch is the best material, and therefore no suggestions have been made regarding the structure of the roof. The reason for choosing thatch is that it is permeable to air, and so there will be a direct draught. It may be mentioned here that a lot of air escapes into the charging room, keeping it warm and dry. It is also advantageous to have a rotating cowl at the roof peak; an old car wheel will provide a very good pivot.

It is recommended that the trays be 3 ft. wide and 5 ft. long, made of 3 in. x 1 in. or 2 in. x 1 in. stuff, and bottomed with light coffee wire. The boxes themselves are 10 ft. deep, but, if trays 10 ft. long are made, it will be found the warping is often so great that the trays are liable to jam. In putting the 5 ft. trays into the box the second will push the first into place, the guides keeping the tray square. A simple hook at the end of a stick will enable one to withdraw the second tray. The short trays allow of a narrower charging room; with 10 ft. trays the room would have to be 13 ft. wide. Also, with short trays only one boy is needed for charging and discharging.

The total drying area in the drier illustrated, with five tiers of trays in position, is approximately 750 square feet. The best loading for a tray is 3/4 lb. per square foot, which gives a fair depth of fresh flowers but a very scattered covering of dry flowers; say, for simplicity, one debbie of 10 lb. per tray. When full, there will be the equivalent of 560 lb. fresh flowers, or, at the lower rate, 50 debbies. At a low rate of drying (say, 12 hours; flowers have passed through in 6 hours), the drier should deal with half a ton of fresh flowers, or 100 debbies, a day.

Two objections have been made to this drier, which, to the writers, appear frivolous. The first is that it will require supervision by night, and so will be impossible to run. The second is that, since the main lot of flowers will be received in the afternoon, it is essential to put all into the drier at once, or they will spoil. As regards the first objection, practically all pyrethrum driers are now run continuously, and by night are supervised by a boy; probably he does doze off in the early morning. The same supervision will do for this type of drier. A break in the heating will lengthen the time of drying for an hour or so. It will take little time to teach a boy when the flowers are ready to be removed, and the 5 ft. trays can easily be worked by a single boy. Should it be feared that mistakes may be made, the capacity of the boxes can be increased to ten tiers apiece for night loading only. The lower trays will be more or less dry, and will not obstruct the air flow a great

deal. By day, however, the normal running should be employed, i.e. no more than six tiers of trays.

As regards the second objection, most pyrethrum growers still sun dry to a certain extent, and therefore have a number of light trays for the purpose. Could these not be used for overnight storage?

The oast house drier, which, in most cases, is inefficient, should be considerably improved by the adoption of the principle employed in this drier. The present tray racks would be replaced by the same enclosed boxes. It might be necessary to widen the passage; or, on the other hand, the trays could be half the depth, as in the Ainabkoi drier. The writers feel confident that such modifications would be amply repaid by increased speed of drying and decreased consumption of charcoal.

Tunnel Driers.

The Ainabkoi Drier, as designed, will deal with about half a ton of fresh flowers a day. There appears to be no reason why the drying chamber should not be lengthened and widened, but, if this is done, it will be necessary to alter the flue lay-out. Up to a length of six boxes and a width of 12 ft., the present arrangement of flues will suffice. Between 12 ft. and 15 ft. in width would necessitate an extra longitudinal flue; probably 15 ft. will be the limit of width. With increasing length it will be necessary to have two fire-boxes at opposite ends of the firing compartment, with two systems of flues overlapping each other. If this alteration be not made there is a certainty of the heat distribution being most uneven.

Long-continued studies of the mechanics of drying have been made in the United States, where it has been found that the tunnel system of drying is the most efficient. In this the hot air travels in a horizontal direction over the material exposed in shallow trays, which are moved along the tunnel in light trolleys.

There are two directions of movement —with the current of air (parallel current), or against the current of air (counter-current). In the parallel current flow, the fresh material enters the tunnel at the hot end and leaves at the cool end; in counter-current flow the reverse is the case. From a purely theoretical aspect, parallel current flow is the more economical, and, owing to cooling effects by rapid evaporation, the safer; but, as has been shown earlier, there are serious practical difficulties which make it impossible for pyrethrum. It is essential with the true tunnel system to use counter-current flow.

The air may, after passing over the material, be permitted to escape (through-draught system), or the greater portion of it be re-heated and again passed through the tunnel (re-circulatory system).

There are a few driers in Kenya operated on the through-draught system, though perhaps they should not be termed tunnel driers. In these the hot air is forced in a more or less horizontal direction through a room over the flowers. In one of these the main flow of air is caused by a powerful exhaust fan. In others, the draught is produced by a chimney stack. In this type there is a serious loss of hot air, since in a large room it is impossible to restrict the air flow to the trays.

In the true tunnel type the air flow is restricted to the tunnel, which is nearly completely filled with trays. A few through-draught tunnel driers have been constructed experimentally. It would be premature to describe these before it is known how they behave.

In the through-draught tunnel driers the air picks up a little water only, and

escapes while very warm. If the air could be made to pass over the heaters again, it would absorb very little heat in reaching the temperature of the hot end, thus saving fuel. Although the theory of this has been discussed earlier, it will not be out of place to repeat it here.

Suppose the air outside is at a temperature of 60° F. and is heated to 120° F., and, in passing over the flowers, drops to 110° F. To heat each pound of air will need $\frac{60}{4.2} = 14.28$ B.T.U., and will give out 2.38 B.T.U. during its passage down the tunnel, i.e. one-sixth of the heat has been utilized. If, now, this very partially saturated air is re-heated from 110° F. to 120° F., each pound will take up only 2.38 B.T.U., the same amount as is given up to the flowers, i.e. all the heat supplied to the air is used for evaporation of water. Very few circuits would, however, suffice to saturate the air, when it would no longer part with heat nor take up water. It would be impossible in practice to expel all the air when it reaches saturation or to dry the circulating air cheaply. Therefore it is the practice in re-circulatory driers to arrange an exit through which a portion of the air is expelled, and an inlet to take in an equivalent quantity of cool air.

For argument, let it be assumed one-sixth of the air is expelled and the same amount driven in. Thus, of each pound of air passing over the flowers, five-sixths is re-heated, taking up $\frac{5 \times 2.38}{6} = 1.98$ B.T.U. The one-sixth pound of cold air at 60° F. being heated to 120° F. will need 2.38 B.T.U. The total heat needed will be 4.36 B.T.U.

In the through-draught, 14.28 B.T.U. had to be absorbed by the air to supply 2.38 B.T.U. for vaporization of water. Therefore, in the re-circulatory type of drier, under the conditions postulated, the fuel consumption is $\frac{4.36}{14.28} = 0.30$ of that used in through-draught. With an increasing temperature drop, the saving in fuel consumption is considerable.

It will be realized that, in order to make the air re-circulate, it will be necessary to have a fan, driven by power, in the circuit. Whether this be a propellor or an impellor fan will depend on the construction of the tunnels. The deciding factor will be the comparative cost of fuel and power. If fuel be expensive, then the saving will cover the cost of driving the fan; otherwise the installation of a re-circulatory tunnel drier will not be economical.

It is not intended to produce a sketch plan of a tunnel drier. Two or three re-circulatory driers have been or will be in experimental use, and until data have been gleaned it will be premature to describe them. The principles only have been discussed, so that anyone desiring to experiment may do so.

Since the above was written, some further suggestions and information have been received from Mr. R. O. Barnes.

The time taken for changing the trays in a compartment is a matter which has caused some concern. Mr. Barnes timed his boys changing a box of six 10-foot trays; that is, removing the tray of dry flowers, moving down the other five, and putting in a tray of wet flowers. The whole process took three minutes only.

He has also worked out that an Ainabkoi Drier in stone with thatched roof, and complete with coffee-wire trays, should cost approximately £50.

In conclusion we wish to thank the many pyrethrum growers who have permitted us to inspect their driers, who have conducted experiments for us, and have made valuable suggestions and supplied data.